Procedural Learning in Virtual Environments and Serious Games

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Love, Patience & Prayer
My husband, kids and parents
(2013 – 2017)

Declaration

I hereby declare that this thesis is my work, and the contents are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university, except where specific reference is made to the work of others.

Nor Nazrina Mohamad Nazry
September 2017

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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

[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.

Chapter 2

Literature Review

Contents

In this chapter, a survey of recent work in some areas that are relevant to the research is presented, in particular, constructivism and learning in virtual environments, virtual reality technology, presence and navigation in virtual environments, serious games, procedural learning, knowledge transfer, moods and emotions, instruction (information) modalities and gender differences. In the end, a review summary is provided. The discussion in this chapter is important because it is used to highlight the factors and elements investigated in the following studies (Chapter 4 and 5). Also, the findings from previous works are used to identify gaps in knowledge and justify the current findings.

2.1 Constructivism, a Learning Theory in Virtual Environments

Virtual environments incorporate three-dimensional (3D) models of a real-world setting and have been used as a reliable tool for learning and training [1]. Also, virtual environments have been widely used as an alternative platform to support traditional methods of teaching and learning. As virtual environments can simulate a situation in the real world, they can also offer learners close engagement to the environment and its contents [2]. The engagement, consequently, allows rich and constant knowledge transfer to learners. However, all efforts to introduce and implement a new method of learning should be based on a solid pedagogical theory [3].

Constructivism is an excellent pedagogy in education. It indicates that people build their perception of the world through experience. Moreover, it has been identified as the fundamental theory which underlies the understanding of how learning occurs in virtual environments [4, 5]. This pedagogy was firstly introduced by Jean Piaget and John Dewey who researched childhood development and education. Since then, it was gradually used, and subsequently, Lev Vygotsky and Jerome Bruner added new concepts into constructivism, which have been used by researchers until now.

This section presents the relationship between constructivism and learning in virtual environments. It firstly presents a discussion on constructivism according to the philosophers' opinions above. In addition, it explains some constructivist approaches which have usually been implemented in virtual environments.

2.1.1 Review of Constructivism

Constructivism considers learners to be active while learning. They absorb the information presented to them and afterwards, they subjectively construct the ideas. Constructivism, moreover describes that learners do not only understand the information they gain, but they try to associate it with prior knowledge. By performing these behaviours, a new mental representation is created. The previous knowledge was defined as 'schema' or building blocks of knowledge by Piaget [6]. In other words, constructivist theory indicates that knowledge is built based on what learners do, promoting an interactive learning as they are not in a blank state.

Apart from that, the constructivist theory states that learners are granted an ownership of what they learn and explore. Although some people have different interpretations of knowledge, constructivism emphasises the role of learner who has the freedom and control of the learning process. Thus, the power of learning shifts to learners. They, therefore, need for them to be active because they choose what and how to learn, as well as how they assess their learning progress. This learning process is commonly called student-centred learning which was introduced first by Rogers [7, 8].

According to Dewey [9], learning should be based on real and authentic experience that can be applied into daily life. Experiencing things and reflecting these experiences, further learners' curiosity of the world and how things work are generated. Also, learners construct their ideas of the world rather than just acquiring them. Based on Kolb's learning theory, when learners experience something new, they will start questioning, conceptualising and implementing the ideas to look for the results [10]. Therefore, learning should be experiential and experimental as suggested in constructivism to promote beginners to advance their knowledge by the end of the learning session.

The constructivist theory also states that learning is transferable through interaction. The social aspect of learning was introduced by Vygotsky [11]. He believed that 'social constructivism' plays a major role in the learning process, which leads to group thinking. Learners learn how to express their thoughts clearly and exchange their ideas through social negotiation while collaborating with peers. They, subsequently, evaluate their contributions to the group works. This theory furthermore eliminates the sense of competition amongst learners, so contributing to a healthy and productive learning environment. Vygotsky's second principle, 'zone of proximal development' also shows that learners' ability is different when working independently and when working with a peer. He concluded that interaction with a peer is an effective process to generate better ideas and develop more effective skills.

When encountering problems, people think creatively by combining their previous experience with current hypotheses of the environment [12]. To discover an optimal solution, they actively observe and interact with the world. People normally explore, inquire and investigate while looking for information. Thus, they easily remember the knowledge as they discover it by themselves. As mentioned by Bruner, learning works better by discovering the knowledge rather than learning through explanation from others or rote memorization [13]. He also believed that ideally, an interest in the subject matter is the best stimulus for learning and that educators should equip students with skills and desire to learn.

2.1.2 Constructivist Approaches in Virtual Environments

There is a large volume of published studies describing the role of constructivism in virtual environments. Previous studies have shown that the combination of virtual environment and constructivist approach is an efficient method to deliver knowledge to learners, in particular, the knowledge that one is not able to experience in the real world. Apart from that, the constructivist approaches have been broadly used in virtual environments to achieve desirable learning outcomes, for example, 1) active learning, in particular, role playing and student-centred learning, 2) situated and experiential learning, 3) collaborative learning, and 4) discovery learning, especially problem-based learning.

2.1.2.1 Active learning

While learning in a virtual environment, constructivism initiates active participation that encourages learners to generate new understanding from their interaction with the environment. As virtual environment provides a strong sense of presence that can be defined as the emotional state of 'being in' the environment [14, 15], learners are involved in the first-hand experience [5] that provides direct knowledge transfer. Driving from constructivism, the following learning models guide the practice of active learning:

Role playing
Multiple representations in virtual environments contribute to various roles and experiences, which can be practised and assimilated by learners. Through avatars, a 3D representation of characters, learners experience a role according to specific characteristics and personalities. The graphical representations positively motivate learners to feel, think and reflect via the role they play. Learners, therefore inspire themselves to widen their creativity and imagination [16].

Previous studies have indicated that learning through role-playing in virtual environments improve users' performance. For example, in Appalachian Tycoon, Ye et al. [17] created role as a bank customer which required students to invest money wisely to develop stream bank as well as to maximise economic and environmental benefits. During a story creation activity, children controlled avatars they liked and communicated with each other which inspired them to create their stories and perform it as a team [18]. In the work of Johnson et al. [19], children had to be an astronaut and mission control while collecting objects around the planetary body both in Asteroid world and Earth world. Roussos et al. [20] built an avatar of a group leader which required a student to work with other students, and the results show that the role of leader enabled students to remain engaged in the learning process.

Student-centred learning
Virtual reality has a few interesting features that assist learners in controlling the learning process in virtual environments by themselves [5]. Firstly, the characteristics of the first-person view allow learners to gain and experience knowledge directly. Non-symbolic representations moreover can be created to encourage learners to construct new knowledge without requiring them to know the entire subject in the first place. Also, size, transduction and reification can be used to experience learners a situation that out of daily life. While learning, the features motivate learners to find the resources of knowledge and at the same time, evaluate their current progress [21].

Some studies have reported the use of the virtual environment for student-centred learning. For instance, in a virtual mine training system called Look, Stop and Fix [22, 23], workers identified potential hazards while navigating in the underground workplace and also specified correct actions to fix it. If they ignored the hazard or chose a wrong solution, the disastrous result would be displayed immediately. In the study by Cooper [24], a serious game that simulated the variety of foods, was created, ranging from fast foods to traditional ethnic foods, as choices to players. Players were then able to visualise the effect of each food intake to their health according to health statistics given. Although it was a game, it showed to players that the balanced diet is imperative in real life. In the virtual community called Bellwood, nursing students were introduced to a patient named Fiona who had recently developed diabetes mellitus [25]. Students explored Fiona's house and her neighbourhood to analyse the present lifestyles and also performed Blood Glucose Monitoring on her.

2.1.2.2 Situated and experiential learning

According to constructivist theory, learning should be based on actual situations that place learners in realistic settings so that learners can contextualise ideas accurately [26, 27]. In other words, the true representations of the world are necessary to construct the knowledge. The principle is clearly relevant to virtual environments as it can simulate a real world case scenario to learners. Virtual environment moreover can imitate the actual situation in a safer environment for learners, especially for beginners [28].

As described before, virtual reality allows learners to interact through multiple representations of objects in the environment actively [29]. For instance, learners can view 3D objects from several angles by performing 'rotate' and 'zoom' function. The frames of reference indicate many aspects of models in the real world which support accuracy and better experience.

Numerous virtual environment applications have been developed in different fields to enable the construction of contextual knowledge. For example, students learned about the history and culture of the Mandan people a long time ago by performing a few tasks in the ancient village called On-A-Slant [30]. Brough et al. [31] built Virtual Training Studio (VTS) which allowed trainees to learn mechanical assembly operations such as recognising, assembling and orienting the parts accurately. In Virtual Playground developed by Roussou et al. [32], children learned about fractions by picking blocks and covering a selected area. Pasqualotti and Freitas [33] developed the virtual city namely MAT^{3D} to show students that the 'real' objects they interacted with were represented by mathematical models. In the work of Crosier et al. [34], students learned about radioactivity in Physics curriculum by performing experiments in the Virtual Radiation Laboratory. Dede et al. [35] created three different worlds such as NewtonWorld, MaxwellWorld and PaulingWorld that asked students to carry out the science experiments. In the study by Roussos et al. [20], children learned about simple biological concepts of plants such as how to plant seeds, effects of sunlight on plants and monitored their growth in the virtual garden.

2.1.2.3 Collaborative learning

Vygotsky [11], in his study of Social Development Theory, assumed that 'social constructivism' has a major impact on the learning process. Learners construct ideas and collaborate with others by articulating their thoughts. Interestingly, virtual reality supports this theory by enabling learners to manipulate the contents of the virtual environment actively and concurrently exchange their ideas with others who are involved in the same environment. The collaboration in virtual environments furthermore encourages learners to be aware of each other in the control environment.

Virtual environments support collaborative learning by involving multiple users simultaneously. They allow learners to work in a group, whether working with more experienced peers such as educators or through collaboration with other classmates. For example, in the work of Kontogeorgiou et al. [36], students discussed with the researcher to construct the virtual quantum atomic model of hydrogen. In the CAVE™ presentation by Limniou et al. [37], the teacher described to students around her about chemical reactions and was followed by a group discussion in the same learning environment. In the study by Chen et al. [38], students were required to explore the virtual earth motion system to answer teacher's questions. Students were also asked to discuss amongst themselves by explaining their findings and showing system operations.

With current virtual reality technology, collaboration does not only occur amongst learners, however, learners may also create 'social negotiation' with avatars. Avatars in virtual environments can be served by computerised residents or representations of other learners [39]. This expansion exactly illustrates a new angle of learning in the artificial environment that provides a better medium of communication amongst users. For example, avatars of students were created to collaborate with virtual residents to save fish population [40]. In the work by Tuzun et al. [41], students communicated with virtual agents in Global Village to collect data about geographic components such as continents and countries. In SMILE™, Adamo-Villani and Wilbur [42] created avatars which interacted with the participants in English and American Sign Language. In E-Teatrix [16], children were allowed to choose and play the character they liked. They then cooperated with other characters played by other kids to perform storytelling. Marshall et al. [43] developed PUPPET which allowed children to control the avatar of sheep and interact with autonomous avatars such as cow and farmer to involve in playful interaction. In Mikropoulos and Strouboulis's work [44], students worked together with avatars to navigate and carry out their tasks in the real ancient Greek house.

Although Multi-user Virtual Environments (MUVEs) are associated with the web, it also indicates a significant impact on learning in virtual environments. The latest MUVEs employ 3D third-person graphics and allow many users to communicate simultaneously in a persistent environment. Collaboration with multiple users at the same time increases the sense of presence that motivates users to keep working to achieve particular goals. Several studies, therefore, exploited MUVEs such as Huang et al. [3], in which medical students from different schools discussed and completed the organ assembly exercises together in a virtual class. In other examples as in the work of Nelson and Ketelhut [45], Nelson [46] and Ketelhut [47], students worked collaboratively to solve the problems including gathering useful clues from surrounding. Students interacted amongst themselves by using a chat window or in the real world.

2.1.2.4 Discovery learning (Problem-based learning)

The constructivist theory also explains that learners increase their experience by discovering the information by their own, as it will force the thinking ability to an optimum level [13]. Sometimes, an actual situation in the real world is impossible to use for learning due to safety and time. Therefore virtual reality technology can be utilised. Thus, making learning process always possible despite whatever reason.

In general, there are few models of discovery learning. However, the problem-based learning is the most common model. A real scenario is simulated to immerse learners to the same context of the problem [3] for free discovery while exploring solutions to solve it. A few areas have applied the concept of problem-based learning in virtual environments, in particular, medical education [48]. For example, in HystSim, gynaecological surgeons performed hands-on training such as myomectomy and rollerball ablation for hysteroscopic surgery [49]. To teach clinical palpatory diagnosis, Howell et al. [50] developed Virtual Haptic Back which allowed students to identify abnormal tissue in the human back. In the work of Tanoue et al. [51], medical students used virtual reality simulator training to increase their fundamental skills such as transfer place and knot tying before doing a real endoscopic surgery. Other than medical education, Holmes [52] offered students to carry out several tasks to save virtual river ecosystems from pollution such as checking whether the river was polluted.

2.2 Virtual Reality Technology

As it provides a recent technology that improves users' performance, virtual reality is used to support existing approaches in education. Thus, this section describes the technology of virtual reality that can be utilised for learning.

2.2.1 Existing Technology

The term virtual reality is understood to mean a technology to create a three-dimensional, computer-generated environment that simulates a high degree of realism and interactiveness of real world or imaginary situation [53]. The simulation is also called virtual environment, a place to accommodate 3D spatial representations [4]. According to Burdea and Coiffet [54], there are three main components in virtual reality which are 'Immersion-Interaction-Imagination', as abbreviated to I^3. Immersion refers to the sensation of being present in a particular world (i.e. 3D world). Interaction can be defined as real-time communication between users and environment. Imagination is a creative conceptualization of knowledge. In virtual environments, the combination of these components stimulates users to explore and understand the knowledge to enhance their experience [3, 29].

The display device that allows users to interact with virtual environments is different depending on the immersion level and method, and the number of users who can participate at one time [37]. Therefore, the virtual reality technology can be categorised into two types such as desktop and stereoscopic display.

2.2.1.1 Desktop display

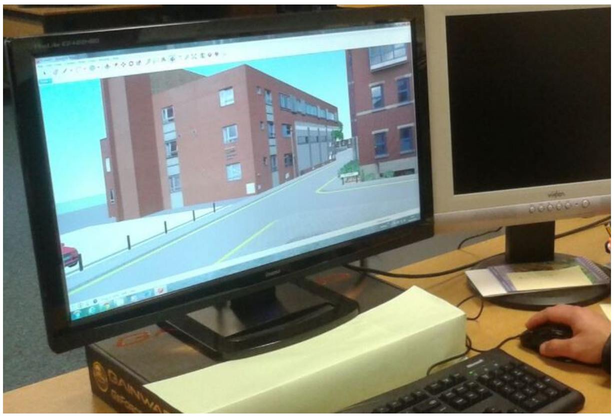


Figure 2.1: Desktop display virtual reality system

A desktop display is also called a non-immersive virtual reality system. Users see a virtual environment through a computer screen, and they interact with the virtual environment using traditional input devices such as mouse and keyboard (Figure 2.1). More than one user can see the virtual environment. However, only one user can control the input device at one time. While the cost of developing and delivering the environment is lower than stereoscopic display, users cannot experience the feeling of the fully immersive environment [3].

2.2.1.2 Stereoscopic display

The stereoscopic display is known as a fully immersive virtual reality system. The stereoscopy is a process where users are shown two images of the same object taken at slightly different angles (one per eye) and the brain combines these two-dimensional images into a single image, generating an impression of 3D depth. In contrast to a desktop display, the stereoscopic display provides the feeling of the fully immersive environment; however, the cost of purchasing and maintaining its special hardware is high [29, 55]. The technology can be viewed in two different displays as explained below:

Head-mounted display
Users wear a head-mounted display (HMD) on the head to view a virtual environment. The device has a small display optic in front of each eye. It is also connected to head-tracking devices that allow users to observe the environment by moving their head only. Typically, users interact with the environment using hand-held input devices such as joystick and game controller (e.g. Xbox 360 controller). Previously, the device was expensive, however, with the latest technology, it can be purchased at affordable cost (e.g. the Oculus Rift which is developed by Oculus VR).

Previous studies have reported that people feel tired when using a HMD and therefore, it is not advisable to use for a long time [3, 37]. However, Chua et al. [2] described that the light-weight HMD was a better choice to use in particular when learning a physical task. Moreover, the recent study by Chessa et al. [56] on the perceptual quality of the Oculus Rift in three different experiments indicated that the device evoked immersive experience and concluded that it could be used in basic research and rehabilitation.

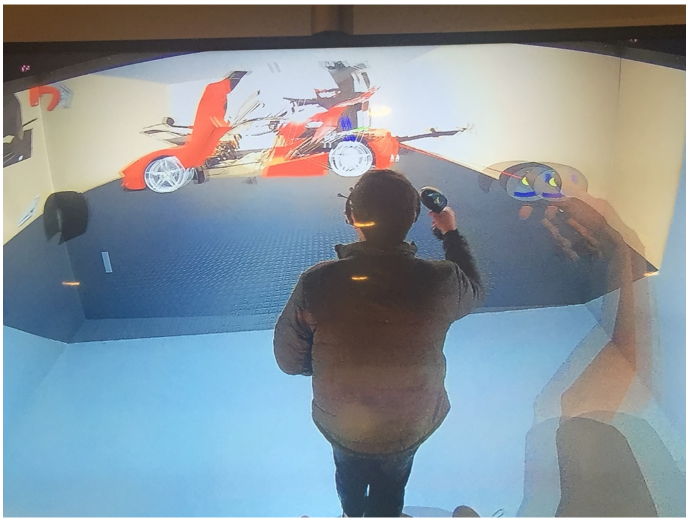


Figure 2.2: CAVE Automatic Virtual Environment (Courtesy of Daniela Romano)

CAVE-like display system
CAVE stands for CAVE Automatic Virtual Environment (also known as Immersive Projection Technology or IPT displays) [57] (Figure 2.2). The high-resolution images are projected to a few walls and also a floor of a cube-like room. The images then appear to float in the air. Users, who wear virtual reality glasses, can walk around in the room to view the objects from different angles [23]. The sensors, which attach to glasses, are

connected to projectors to track users' movements and continually align the videos to retain the user perspective. The standard set up of CAVE consists of projectors, walls, floor, tracking sensors in the wall, speakers at various angles for 3D sound and video that projects a series of images. The common input devices are joystick and data glove. The advantage of the system is it allows a few users to participate collaboratively at one time.

2.2.2 Issues on Technology

Chittaro and Ranon [29] described that users were not able to follow teacher's explanation (verbal, written or action) when they were putting the HMD on or when they were located in the CAVE, although both stereoscopic displays provide full immersion to users. However, Limniou et al. [37] reported that a group of five students, who were located around the teacher in the CAVE, actively observed and listened to their teacher's description of a chemical reaction. The teacher wore the tracking system to observe the virtual environment and used the joystick to control the molecules and chemical animations. Meanwhile, all students wore the stereo glasses to enable them to conceptualise the description immediately. They also commented that the CAVE was a good platform to participate actively with their classmates.

2.3 Presence in Virtual Environments

Presence in virtual environments refers to users feeling 'being in' an environment [58, 59] that is induced by elements in the environment, although the environment is not existing and users' body is physically situated in another place. It is also defined as 'place illusion' (PI) by Slater [60] that indicates the way people interpret a virtual environment, although they know that they are not in the environment. Previously, Sanchez-Vives and Slater [61] described presence as for how people react realistically in a virtual environment, and their reaction is measured by physiology, emotion and behaviour parameters. Besides, Wallach et al. [62] described that the experience of 'being in' an environment is subjective based on users' judgement; however, it is affected by personality and technological aspects [63, 53].

The following sections present two concepts that influence presence in virtual environments, in particular, immersion and viewing type (first-person and third-person view).

2.3.1 Immersion

Slater and Wilbur [64] used a description of the characteristics of a virtual reality system to describe the concept or immersion. The characteristics show the quality of the experience of displays and tracking such as the quality of the images and the overall extent of tracking. They also mentioned that the immersive capability of a system is affected by five aspects such as inclusive, extensive, surrounding, vivid, and matching. In another view, Slater [60] explained immersion as valid actions that are possible within a virtual reality system.

Miller and Bugnariu [65] described the relationship between the level of immersion in virtual environments and patients with autism spectrum disorder (ASD) to learn social skills. They grouped previous studies into three levels of immersion: low, moderate and high. They found that each level can help the patients differently, for example, low immersion systems can show some differences in social performance. In 2001, Mania and Chalmers [66] investigated the effects of levels of immersion on memory recall. They recruited 72 volunteers and divided them into four conditions: real, 3D desktop, 3D Head Mounted Display (HMD) and Audio-only. The results of questionnaire indicate that the level of immersion was not positively correlated to precise memory recall in all conditions.

2.3.2 First-Person View versus Third-Person View

There are two types of knowledge perception in virtual environments such as first-person view (egocentric viewpoint) and third-person view (exocentric viewpoint). The first-person view can be defined as perceiving knowledge directly and perhaps, unconsciously whereas the term third-person view refers to perceiving knowledge through an intermediate object which requires informed judgement [29]. Recent studies have shown that the first-person view is widely used to allow the knowledge transfer occur consistently. However, according to Chua et al. [2], they found that the third-person view benefited users in a scenario which required a view of whole body motions, for example, a one-to-one method of teaching. In their study, students copied motions in Tai Chi virtual training correctly because they were able to view every slow motion of the teacher in front of them. In contrast to Chua [2], Yang and Kim [67] showed that the third-person view was not suitable for fast motions because users were not able to copy quickly due to the limitation of short-term memory and as a result, they did not pick up all knowledge as expected in the learning objectives.

2.4 Navigation in Virtual Environments

Navigation refers to a journey through a virtual environment while discovering information from different positions and orientations [68]. This various information is then utilised to form spatial cognition of the environment [69]. When navigating, people also show some patterns of physical movement due to varied input such as 1) prefer to move with the flow, 2) try to avoid a crowded area, 3) walk on one side where they normally prefer to go to the right, and 4) try to finish the navigation quickly [70].

This section discusses a few components of navigation in virtual environments, in particular, spatial knowledge, survey and route perspective, and landmarks.

2.4.1 Spatial Knowledge

While navigating in a virtual environment and real world, users need a mental map. Most of the information is usually gathered through a visual channel and integrated with other information, such as spatial and olfactory, but also by following navigation instructions. In virtual environments, the visual information is provided as a 3D image, and it is possible to have further spatial information coming from the environmental sound (e.g. stereo sound), but normally the most accessible source during movement is acquired from visual information [71]. As users move through a virtual environment, their spatial knowledge becomes more robust [72, 73]. Ruddle et al. [74] reported that users could improve their spatial knowledge and navigation memory by repeatedly navigating a virtual building. The findings were also supported by more recent studies [75, 76] that users with more extensive navigation skills develop more solid spatial knowledge of a place than those with poor spatial abilities.

2.4.2 Survey and Route Perspective

Two types of viewing perspective are typically used to navigate in virtual environments, such as Survey and Route. The Survey perspective shows a map-like view, whereas the Route perspective shows a first-person view. Different studies in literature seem to favour one or the other, for example, Brunyé et al. [77] compared the survey and route modality and found that participants took more time to navigate if the route was solely learnt from route perspective. By contrast, Ruddle et al. [74] found that after learning from route perspective, participants' spatial knowledge was as accurate as, and in some cases, more accurate than spatial knowledge acquired after learning from survey perspective.

2.4.3 Landmarks

Landmarks are an important cue to show users their current position and orientation while completing a navigation task. Previous studies have shown that during navigation, participants use landmarks to create associations between the present location and the target position, and also to change their direction [74]. Jansen-Osmann [78], in his study on the role of landmarks in a virtual environment, found that participants learned faster in the maze that contained landmarks and they recalled more landmarks which were located close to turns in the environment. Moreover, Ruddle et al. [74] found that the use of common and identifiable landmarks eased the route finding and increased the level of memory recall. Brunyé et al. [77] reported that they found that the more time participants took to memorise the landmarks, the more accurate they located the landmarks on the paper.

2.5 Serious Games

Serious or applied games are games that are used for objectives other than pleasure and pure entertainment [79]. This approach receives much attention from different fields as it provides immersive experiences that positively encourages learning processes [80, 81]. This section discusses the differences between video games and serious games, gamification and the relationship between serious games and learning.

2.5.1 Video Games and Serious Games

Players in any age categories normally play video games for fun. However, video gameplay has abilities to stimulate challenges, teamwork, engagement, and problem-solving skills [82]. Seaborn and Fels [83] list some game characteristics such as rules, structure, voluntary participation, uncertain outcomes, conflict, representations of some reality and resolution. Also, Dondlinger [84] includes rewards system, goals and narrative context as game characteristics. When playing video games, different players have different perceptions of gaming experiences [83].

On the other hand, players play serious games for purposes beyond amusement. Serious games are designed to fulfil a set of targeted learning objectives or to build an engaging environment that provides skills development and behavioural transformations [85] for which they have been created. They can have the same look and feel, and characteristics as video games with the aim of engaging learners further in the task. For example, to win a game, students learned to code their programs [86], players tracked an object better after playing an action game [87] and students improved prosocial behaviour despite playing computer games in which they had to kill some of the entities [88].

2.5.2 Gamification

Gamification can be defined as the use of game design elements in different perspectives other than traditional video games [89]. It potentially improves users' desire to get involved in experiences that are originally not fun [90, 91] through meaningful contact and engagement with the environment [92]. Five motivational factors are recognised to sustain players' engagement in the gameplay such as achievement, exploration, sociability, domination, and immersion [93].

Although gamification is new [94], two acceptable notions can be used to understand its theory [95]. The first notion is reward-based gamification such as point systems, levels, leaderboards and so on [96], and the other notion is meaningful gamification that emphasises play, exposition, choice, information, engagement and reflection. As noted by Nicholson [95], for instant and short-term improvement, the former may be an appropriate approach, however, for long-term improvement, the latter may be necessary for game designers to influence players.

Due to immersive experiences, players are highly exposed to be in a state of flow when playing a serious game. Flow is a psychological state that is represented by absorption and satisfaction during game playing [97]. According to Broin [98], players require three essential conditions to experience flow such as clear goals, instant feedback, and a balance between challenges and their skills. Also, Hamari et al. [99] indicate that flow is generated by a combination of high challenge and high skill that affect playing experiences and learning outcomes.

Hunicke et al. [100] developed a model that describes game design elements, called the MDA model (Mechanics-Dynamics-Aesthetics). Game mechanics highlight game components such as achievements and badges while game dynamics show the relationship between players within the system, for example, freedom, progression and teamwork. Game aesthetics are experiences generated from emotional responses in players while and after playing, such as moods. In 2011, Botella et al. found that game design elements reduced the level of fear and avoidance in treating cockroach fear as compared to traditional treatment [101].

2.5.3 Serious Games and Learning

Previous studies have shown that serious games can play a vital role in education and its potentials to influence learning effectiveness are unquestionable. For example, a game called *It's a Deal!* was created by Guillén-Nieto and Aleson-Carbonell [102] to study serious games involvement in intercultural communication and the results indicate that serious gaming was an effective platform to increase awareness and knowledge. Bakhuys et al. [103] examined the effectiveness of serious games in three experimental studies, and the findings demonstrate that participants who played the serious games scored higher on high-quality learning elements and also, serious games were a more efficient tool to self-report learning outcomes as compared to classroom settings.

2.6 Procedural Learning

Procedural learning (or procedural knowledge) is the same concept of 'knowing how' [104]. The term can be defined as learning and construction of steps that subject to certain rules and facts in completing a task. Knowing how, in other words, is a major factor in the success of a task performance. However, Stanley and Williamson [105] argued that knowing how is a species of 'knowing that' (or descriptive knowledge), which is knowledge about factual information. In a different view, Refeng [106] claimed that knowing how does not about know a fact, but it is the ability to perform certain kind of things.

The following sections describe procedural learning in virtual environments and serious games.

2.6.1 In Virtual Environments

In virtual environments, procedural learning has been used to accomplish different goals. For example, Ganier et al. [107] developed a virtual training to teach tank maintenance procedure and compared it with traditional training (using an actual tank and preparation station) and no training (control). After a training session, participants were asked to perform the procedure in the real environment. The results from 42 samples indicate that participants in the virtual training group performed the same level as in the traditional group. Jou and Wang [108] examined the influence of virtual environments to teach technical skills in undergraduate students. Participants were divided into two groups in receiving instructions: traditional method, and virtual training method. After one semester, their technical skills were evaluated, and they found that virtual training was effective to learn about the operation of machines, selection of process parameter and process planning.

Procedural learning in virtual environments is also applied in the medical context. For example, Källström et al. [109] investigated the effects of a full procedure simulation model for transurethral prostate resection in 11 medical students and 9 experienced urologists. The participants were asked to perform several full procedures in the simulator with different levels of difficulty before answering the questionnaires. The results from training simulator indicate that the students improved their performance and they concluded that the simulator could be used to teach a full procedure in the early training of urology students.

2.6.2 In Serious Games

The same findings have been revealed in serious games. Rhodes et al. [110] examined the effects of serious games on teaching and reducing cognitive biases in decision making. They compared between game-based training and control groups (video) and evaluated participants' knowledge immediately after training and after a delay. They discovered that serious games delivered knowledge better in bias mitigation skills (procedural knowledge). Hulteen et al. [111] studied movement skills in children after playing active video games. Nineteen children volunteered in the study, and their skills were assessed before playing the games. Their skills then were monitored once a week for six weeks. The authors discovered that children improved their skills performance, in particular when playing table tennis, tennis, and baseball. Adams et al. [112] examined the influence of video games in improving laparoscopic skills of surgical residents. They compared amongst three groups: traditional laparoscopic simulator, XBOX 360 and Nintendo. After six weeks of practising on the consoles, the authors found that participants who played video games improved their skills more than participants who used the traditional simulator.

2.7 Knowledge Transfer

Knowledge transfer is a fundamental concept of learning. Knowledge transfer can be defined as applying knowledge that is learnt in new and different learning situations [113]. Bossard et al. [114] listed three conditions that can affect knowledge transfer in virtual environments: vertical and low road transfer (low), horizontal and high road transfer (high), and horizontal and near transfer (rich). They also claimed that the effectiveness of virtual environment for learning or training could be measured by knowledge transfer from a virtual environment to the real world. Ganier et al. [107] stated the same argument, that is, the success of knowledge transfer in virtual environments depends on whether skills learnt from virtual environments can be applied in the real world or not.

The following sections describe procedural learning in virtual environments and serious games.

2.7.1 In Virtual Environments

Bertram et al. [115] examined the effects of virtual training to train the police force in complex collaborative tasks. They divided participants into three groups: virtual training, standard training and 4control group. After training, participants perform a team task in a real environment. They discovered that participants in standard training outperformed participants in the virtual group regarding motivation, the perceived value of the training and knowledge after the training; however, the virtual group was as good as standard training in knowledge transfer to the real world task. Tirp et al. [116] studied the transfer of learning from virtual training into the real environment in dart throwing. The performance was evaluated according to throwing accuracy and quiet eye duration. The results of pre- and post-test were compared, and they found that participants in the virtual group scored higher on throwing accuracy than the other two groups (real and control), and participants in both virtual and real training improved their performance in the post test. de Mello Monteiro et al. [117] observed the relationship between motor performance and learning of individuals with cerebral palsy in a virtual environment. Sixty-four participants were recruited, and they were asked to perform two coincidence-timing tasks. The participants increased their coincidence timing in both tasks; however, authors did not detect any knowledge transfer in practice. They suggested that motor rehabilitation for individuals with cerebral palsy in virtual environments need to be studied carefully.

2.7.2 In Serious Games

Previous studies have also considered knowledge transfer in the serious gameplay. Parong et al. [118] built a custom game called Alien Game to teach the executive function skill of shifting between competing tasks. They compared the game to a control game that did not have shifting. They revealed that participants in the custom group performed better on cognitive shifting tests than those in the control group when they played the game for two hours. Rosas et al. [119] examined the effects of educational video games in school students regarding knowledge acquisition, motivation, teachers' reports and classroom observations. They separated 1274 participants in three groups (experimental, internal control and external control). They found that participants in the experimental and internal groups acquired knowledge better than participants in the external group. However, there was no difference between experimental and internal groups. DomíNguez et al. [120] applied a gamification plugin for e-learning to investigate its effect on learning experiences and found that students who experienced gamification obtained higher scores in practical assignments, however, these students performed poorly in written assignments.

2.8 Moods and Emotions

Moods and emotions are intimately related, but the terms do not represent the same concept. In the opinion of Beedie et al. [121], cause and duration can be used to distinguish moods and emotions. Moods can be generated by increasing effect of numerous events or less specific causes, and it continues hours or days (long-term). Conversely, emotions can be provoked by specific events, and it continues seconds or minutes (short-term). Furthermore, moods are slow reactions that influence feeling state and cognition, whereas emotions are quick reactions that affect feeling state, behaviour and physiology [122]. However, moods and emotions have 'transactional relationship': present mood can affect people emotional reaction to an event, in which the results of the emotional reaction can influence the mood in the end [123].

In psychological research by Zillmann [124] on mood management, it was found that people try to improve their mood through the activity they choose to do. In gameplay, even before they start playing, people pick a genre or another to fit in with their current mood [125], but it is not clear whether the initial mood is maintained or changed following a serious gameplay.

The next sections present a few relationships of moods and emotions with other domains, in particular, with a learning experience, video games and serious games.

2.8.1 In Learning Experience

A learning experience is constructed through the knowledge encountered during learning [10]. However, learners' moods [126] and emotions [127, 128] have been shown as a major contributing factor to a learning experience and determine learners' motivation to continue learning [129]. According to Zull [130], enjoyment and satisfaction encourage learners to move toward a goal. Through this movement, people encounter and learn new things. In his study on fear of learning new things in adults, Perry [131] described that learners are demotivated if they experience a negative mood such as feeling uneasy before, during or after the task . As such, it seems to be important that people feel easy when they acquire new knowledge and that it is hypothesised that a positive mood positively influences learning.

Fredrickson and Branigan [132] investigated the influence of emotion on basic perceptual processing through two continuous tasks: watching film clips that stimulated emotions (positive, negative and neutral) and matching comparison figures to the target figure. They found that participants in positive emotions classified figures from broad perspectives and those who in negative and neutral emotions classified figures from specific angles. Brand and Opwis [133] examined the effects of mood on knowledge transfer in two experiments. The results from both studies show that mood was a significant influence on the transfer, that is, positive mood improved the performance of transfer tasks whether participants learned and performed the transfer tasks alone or in pairs. Liew and Su-Mae [134] explored whether positive and negative moods affect cognition and motivation, and discovered that negative mood increased intrinsic motivation and germane load; however, it decreased the achievement of learning transfer. Bertels et al. [135] studied the relationship between sad mood and statistical learning and found that participants in sad mood enhanced conscious access to their statistical knowledge. In an early research by Rinck et al. [136], they found that mood induction influenced words recall. Their findings indicate that participants in happy mood recalled strongly pleasant words better; however, participants in sad mood recalled strongly unpleasant words better.

2.8.2 In Video Games

In most video games, the game humour has shown to improve players' mood [137] and retain players' engagement until the end of gameplay. For example, when a player wins a game, s/he feels happy [138] and tries to achieve the same or better performance at the next level. Despite the new challenges presented to the players [139], levels in a game seem to preserve players' happiness and stimulate performances. However, games can also be played for other reasons apart from obtaining a positive mood, for example, to relax or as a pastime.

Playing games does not always improve players' mood, and can induce negative emotions such as feeling tired and angry [140], which supports the concerns that some people have with regards to excessive video game playing, in particular among children [85]. In Japan, the cause of unexplained symptoms in 19 children was investigated, and it was found that excessive video game playing at home triggered tiredness (i.e. exhausted facial appearance) and other physical negative signs [141]. Likewise, players who became addicted to online games playing developed mood disorders [142].

2.8.3 In Serious Games

Serious games are games created to fulfil an objective rather than for pure entertainment [143]. Fernández-Aranda et al. [144] reported that after playing PlayMancer, a video game therapy for emotional regulation, patients with mental disorders (i.e. impulse-related disorders) felt calmer and used the strategies from the game to deal with real world pressure. Players' emotions and behaviours have also been used as a method for evaluating gameplay in serious games and mapping a game style to players' characteristics [145]. Franceschini et al. [146] described that after playing several hours of video games, children with dyslexia remarkably enhanced their reading skills; however, the game-based learning did not help them developing a better mood. As such, it is not clear whether a serious game positively enhances players' mood after gameplay or not.

Sweetser and Wyeth [147] have developed a model of enjoyment in games experience, named the GameFlow that defines game enjoyment (or flow) as the optimal experience arising from a good game design. The GameFlow includes eight elements: concentration, challenge, skills, control, clear goals, feedback, immersion, and social interaction; but does not consider learning or moods and enjoyments as a feeling. Fu et al. [148] verified and improved the scale developed by Sweetser and Wyeth [147] and validated it for e-learning games. In their work, they substituted questions related to skills, with questions related to knowledge improvement, but again they did not consider dimensions related to players' mood and enjoyment as an emotional state.

In a virtual environment, navigation task has been shown to be a standardised and responsive measure of cognitive deficits in patients with mood disorders [149]. Therefore a navigation-based gameplay is a strong approach for mood assessment in applied games.

2.9 Instruction (Information) Modalities

Instructions can be defined as a set of detailed information about how something should be done [1]. The information can be delivered to learners via one or more modalities concurrently. Ainsworth [150] refers these modalities as multiple representations that facilitate learning processes in different strategies. When discussing the design dimensions, Ainsworth [151] categorises textual, audio and pictorial as 'form' to supply information in a regular multi-media system. However, little work has been done to investigate the effects of the form of a representational system to learning.

The level of detail plays a vital role to convey information to learners. In an analysis of the degree of detail, Brough et al. [31] present three conditions which negatively influence the knowledge acquisition: too little detail on some steps, too much detail on simple steps, and too many high details. However, they suggest that a low detail of information can be used at the beginning of learning process and more information can be added if learners do not improve their performance.

The following section presents a review of information modalities, in particular, textual, sound, visual, companion and combination of modalities.

2.9.1 Textual

Traditionally text is a common modality to deliver information in the learning environment. However, sometimes people need to read text that requires a longer time to complete and understand it. Löhner et al. [152] examined the relationship between different tools (information modalities) in a modelling process to improve students' reasoning. They discovered that students in the textual group designed fewer experiments with their model than students in the graphical group, although both groups spent the same amount of time in the experiment. They concluded that modelling from the text would take more time and effort than modelling from the graphic. Also, information delivered through text allows ambiguity that is not easily found in another modality (e.g. visual) [153].

However, textual performs better when presenting abstract information to learners, and also when arguing more general contradictions [154]. Besides, previous studies have shown that textual benefits learners in some situations. Mashhadi and Jamalifar [155] studied the effects of cues on vocabulary learning and assigned 90 students in three groups: visual, textual and control. For the textual group, they presented words with additional cues, for example, the keywords were bolded. They found that there was a significant difference between pre- and post-test and claimed that cues gave pos-

[1] https://en.oxforddictionaries.com/definition/instructionn

itive impact to reading as learners focused more on the text. Tapiero [156] examined the effects of text and map of a city in two tasks: spatial judgement tasks and transfer tasks, and discovered that participants performed the first task more precisely after learning from the textual information of the city.

2.9.2 Audio

Giving information via audio is another method of conveying messages to people. Previous studies have shown that audio is used to accomplish a variety of learning goals, either as a principal or supported modality of information delivery [67]. For example, audio instructions were used by sight-impaired people in the Audio-Based Environments Simulator (AbES) to learn about orientation in a space and improve their mobility skills [71]. In another study, Webb and Chang [157] used audio to assist text reading in a vocabulary learning of Taiwanese students who learned English as a foreign language (EFL).

de Oliveira Neto et al. [158] studied the effects of audio and text representation in online learning of Brazilian technical education. In their experiment with 91 participants, they found that participants in the audio group performed better in the transfer test; however, they perceived a lower cognitive load than participants in the text group. Johnson et al. [159] investigated the influence of verbal guidance when learning from abstract and contextualised representations of electric circuits. They discovered that the guidance was helpful to students in the contextualised representation group only, and when without guidance, students in the abstract representation group performed better than the other group. They concluded that verbal guidance could assist learning when less efficient representational formats are used.

2.9.3 Pictorial

Psychologists believe that humans cognitively prefer information through visual as it stimulates the development of a perceptual strategy and also, it increases the ability to recall the knowledge [160]. The modality moreover facilitates a search as it clusters related information together that utilise perceptual processes while learning [161]. Schnotz [154] also agrees with this argument and he, in his study on the learning difference between text and visual displays, claims that visual display is the most suitable to deliver concrete information. Other studies support this claim, for example, Ainsworth and Loizou [162] investigated whether text or diagrams induce any effect to the self-explanation of the human circulatory system and found that participants who learned from diagram performed better than those who learned from text. In 2001, ChanLin [104] examined the effects of information modalities on a computer-based physics lesson in her experiment with 357 students. She discovered that novices learned better from still graphics than text in descriptive learning.

However, when combining pictorial with another modality to deliver information, some studies have shown contrasting results. For example, Ritzhaupt and Kealy [163] investigated the effects of pictorial feedback in learning, and they found that students who read an illustrated story gained lower mark in a recall performance test than students who read a text without pictures. Glaser and Schwan [164] examined the learning relationship between pictures and spoken text. They discovered that pictorial information that was verbally referenced was better learned than pictorial information that was not named in the audio text.

2.9.4 Companion to the Learning Experience

Information delivery via companion can be divided into three categories: real human; avatar represented by a computerised resident or an actual user; and intelligent agent. However, this section just focuses on real human as a learning companion.

Having a companion beside learners in perceiving information is similar to the concept of collaborative learning in virtual environments. The information is easier to understand [29, 67] and it encourages immediate feedback and correction [3]. Vygotsky [11], in his second principle, 'zone of proximal development', concluded that working in collaboration with peers is more efficient to generate better ideas than working independently.

Learning with a companion can be peer learning together with a coach or instructor that also promotes the social aspects of learning [165]. In education, a coach is a form of practice-based teacher [166]. Besides, coaching involves reflection which correlates experiences, in particular, knowledge and skills, to solve problems [167, 168]. According to Schön [169], reflection encourages people to express and analyse problems from multiple angles, and evaluate their inferences and potential solutions. This process directs to critical thinking that involves people to revisit their experiences before making judgements. Smith [170] studied the function of reflection in nursing knowledge, and via written record, she found that student nurses reassessed their and others' experiences to observe the meaning of theoretical explanations. The findings are supported by the work of Lew and Schmidt [171] who found that students reflected in their learning process by performing a critical review of past learning experiences.

2.9.5 Combination of Modalities

The modalities discussed above can be combined when giving information to learners (e.g. instructing students to proceed with a task). As modalities can support each other, therefore it formulates mental mapping of learners to process information actively [154]. Besides, each modality or 'form' has a different strategy to deliver information and solve a problem. When multiple modalities are presented, one modality may decrease ambiguity of another modality [151]. Brown at al. [172] examined the effects of words reading while listening in the vocabulary learning of the second language. They grouped 35 participants in three conditions: text only, text and audio; and audio only. They found that participants who learned from text and audio simultaneously obtained greater vocabulary knowledge than the other groups. Similarly, Webb and Chang [173], in their experiment with 82 students, found that students who learned from text and audio together learned more words than those who just learned from text.

However, in his study on mixed modalities of information delivery, Kalyuga [174] suggests the information should be processed separately. Due to limited working memory, the mixed conditions of presenting information develop risks of overloading capacity that contribute to the split attention effect. Ainsworth et al. [175] investigated the relationship between multiple modalities of presenting information and mathematics lesson. They grouped children in three conditions: pictorial, mathematical, and combination of pictorial and mathematical. The results show that children performed better when solely learned from the modality, but children did not improve their ability when learning from the mixed modalities.

2.10 Gender Differences

Due to different mental functions and behaviours, dissimilarities between males and females are a common context that has been discussed in a variety of fields, including in learning and skills development. Some studies have shown that males score higher than females, for example, boys' performances exceeded girls in oral language, spatial abilities and visual [176], and men obtained higher scores on the need of creating a relationship in online learning [177]. However, some studies have indicated differently, for example, girls outperformed boys in number comparison and word-rhyming tasks [178], and women remembered more phonologically-familiar novel words than men in word learning [179].

The following sections describe gender differences in learning, spatial and navigational abilities, and moods and emotions of gameplay.

2.10.1 In Learning (and Collaborative Learning)

Gender differences have been widely discussed as an interesting topic in the learning environment. The findings do not only indicate dissimilarities on some areas; however, they usually are opposing [180]. Wehrwein et al. [181] examined the gender differences in learning style preferences in physiology students at Michigan State University. They collected the data using the VARK questionnaire: V – visual, A – auditory, R – read-write and K – kinesthetic. They found that men preferred to learn from multiple learning styles. However, women favoured learning from a single style with an inclination toward K, that learning through their senses. Moll et al. [182] performed a study on learning disorders in children. Through their sample of 1633 German speaking children, they discovered that boys outperformed girls in arithmetic, but they were impaired in spelling. Moreover, Diniz et al. [183] revealed that over time girls achieved more significant rises in writing than boys. Previous studies have also indicated interest to examine gender differences in online learning. For example, Barrett and Lally [184] found that on average men sent more messages than women; however, women sent more 'interactive' messages than men as responded to previous messages. Ong and Lai [185] accessed the gender differences in e-learning acceptance of 89 men and 67 women in Taiwan. The results of the survey showed that for men, their usefulness perception was the main factor they used e-learning, but for women, they were influenced by their perception of computer self-efficacy and ease of use.

In collaborative learning, some studies have shown that women prefer to learn with a companion more than men. For example, in their study on collaborative learning through 513 samples, Stump et al. [186] discovered that women used more collaborative approach than men in engineering courses. Also, Chan et al. [187] collected experimental evidence on gender differences in the online social network, and the findings indicate that female students significantly were more active in online communication than male students. Conversely, Prinsen et al. [188] described that males tend to actively participate more than females in collaborative learning, suggesting that both genders utilise advantages of collaborative learning. In further works on gender grouping, two studies revealed that women in single-gender grouping significantly performed better in collaborative learning [189, 190], indicating that this grouping is a good method in collaboration.

2.10.2 In Spatial and Navigational Abilities

Cognitive gender differences have also been examined in spatial and navigational abilities. Previous studies have shown that males have better abilities than females because males have high visuospatial working memory, that is, they can process, assimilate and convert the imagined visual material [191]. Geary et al. [192] hypothesised that men performed better in arithmetic as they had an advantage in spatial abilities and computational fluency. They recruited 113 male and 123 female students and asked the students to answer four tests: arithmetical computations, arithmetical reasoning, spatial cognition, and IQ test. The results present that men had higher scores in the first three tests which approved their hypothesis. Palmiero et al. [193] investigated the relationship between mood induction and sex differences in visuospatial abilities. Participants were required to listen to emotional music while performing on the Corsi Block-tapping Task (CBT) and Walking Corsi (WalCT) test. Before and after the visuospatial task, they completed the Positive and Negative Affect Schedule. Palmiero et al. found that men scored higher than women in the CBT forward condition, however, in the WalCT conditions, they scored higher with negative music.

About spatial abilities in virtual environments, Castelli et al. [75] reported that men outperformed women in the spatial abilities test. They also found that men acquired better information through survey perspective than women (e.g. men made fewer mistakes in locating landmarks on a map). The findings were validated by the work of Nori et al. [194]. They discovered that men performed better than women in a route learning and recalling, whether in the real and virtual reality environment. However, Rodríguez-Andrés et al. [195] did not detect any difference between boys and girls when assessing spatial short-term memory through the MnemoCity task. When considering women only, Walkowiak et al. [196] described that women who usually used the survey perspective completed the navigation task quicker, travelled a shorter distance and made fewer mistakes than those who did not.

2.10.3 In Moods and Emotions of Gameplay

Moods and emotions are produced following a gameplay. Depending on several factors, males and females may create a similar or different emotion after playing a video game. Cooper and Mackie [197] studied the effects of aggressive and non-aggressive video gameplay in boys and girls. They presented three games to the children: mazes, Pac Man and Missile Command. They discovered that boys felt happy playing all games regardless of the genre; however, girls like to play the maze game more than the other two games. Fleming and Wood [198] also examined the influence of violent video games on children's mood. In their experiment with 71 children, they did not find an increase in the aggressive mood for both genders after playing the violent game. However, when comparing with the paper-and-pencil game, they found a significant rise in a positive mood for both boys and girls after playing the violent game.

Lee et al. [199] used a 30-minute active video game to change children's mood. They recruited 134 participants and asked them to complete the Brunel Mood Scale (BRUMS) before and after the gameplay. The results show that the game significantly reduced anger or depression in children. Regarding the gender difference, they, however, found that the game contributed the same mood effect to both boys and girls. The findings are similar to the results obtained by Israel et al. [200]. They investigated the relationship between game content, learning disability, reading level and gender in playing science video game. The results show that there was no significant difference between boys and girls in learning performance. In another study, Weaver et al. [201] investigated the influence of video gameplay on adults' health. When considering females only, they found that video gameplay caused players face greater depression than non-players.

2.11 Review Summary

To summarise, the literature indicates that constructivism plays the main role in learning in virtual environments. Also, virtual reality technology that has great immersion positively influences learners. While navigating in virtual environments, spatial and landmarks knowledge, and presence are important factors to support the learning process. Apart from that, external factors such video game elements, moods and instruction modalities can be correlated as it stimulates users whether to perform better or not.

The previous studies have presented some questions that will be examined in this research according to the aims in Section 1.3, Chapter 1:

1. With the features that virtual environments and serious games have, these representations are considered an effective platform to inform learners on how to

perform a thing, however, would it be good (or better) to learn how to navigate a route as compared to Google Street View, and to learn how to perform a ritual as compared to PowerPoint note?

2. Text, audio, visual and companion have advantages and disadvantages when delivering information, so is it same on a route and ritual learning, and what is a better representation in these two situations?
3. Moods and emotions influence learning whether before, during and after, if people learn while navigating in the environment, does this learning style change a current mood and induce a better emotion?
4. Virtual environments improve people knowledge and skills, but, can it supply enough knowledge of procedure that can be applied in real world?
5. If yes, how long can it remain, whether just for immediate effect or after a delay period?
6. Males and females perform differently in some conditions, would they outperform each other or indicate the same performance in the elements raised previously?

2.12 End-of-chapter Summary

In brief, learning in virtual environments and serious games can utilise the constructivist theories, especially experiential and collaborative learning. While learning and navigating in virtual environments, some internal and external issues of virtual reality can be considered to examine its consequences to the learning process and outcomes, such as spatial and landmarks knowledge, presence, game design elements, moods and instruction modalities.

Chapter 3

Case Study: Sa'ie

Contents

In this chapter, the case study of Sa'ie is presented. Sa'ie is an essential ritual (or *Rukun*) in Hajj and Umrah. This chapter firstly describes the importance of Sa'ie as the case study. It then explains Hajj and Umrah followed by a complete discussion of the Sa'ie ritual. In the end, it present a literature review related to Hajj and Umrah in virtual environment research. The discussion in this chapter is important because this case study was used to develop a serious game of Sa'ie and the game was tested in Study 2 (Chapter 5).

3.1 Importance of Sa'ie as the Case Study

Sa'ie is an essential ritual in Hajj and Umrah that without it, both pilgrimages are considered invalid. It is complex because pilgrims are required to navigate on the prescribed path and also to perform specific actions. As it is a ritual of Hajj, it is done by many pilgrims at the same time. Pilgrims are provided with some materials about it; however, they still cannot imagine a real situation. Also, recent works on ritual simulation have shown a few gaps that need to be improved (e.g. focus on crowd simulation only and poor contents presentation). Therefore, translating Sa'ie in a serious game is a good choice for ritual learning in a virtual environment. A detailed description can be seen in Section 3.4.

3.2 Hajj and Umrah

3.2.1 Introduction to Hajj and Umrah

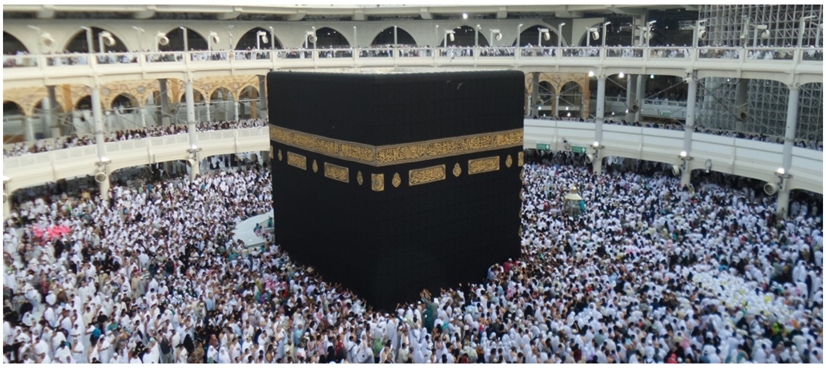


Figure 3.1: Masjidil Haram, Makkah, Saudi Arabia

Hajj and Umrah are both Islamic pilgrimages to Makkah, Saudi Arabia, which involve visiting the Kaabah[1] (Figure 3.1). Kaabah is the known black cuboid building that is located in the middle of Masjidil Haram[2] [202]. Since 624 CE, Kaabah has acted as the direction where each Muslim in the world should face when praying [203]. The Arabic word of prayer is *Salat*. Also, Kaabah is expected to be faced by Muslims when performing other rituals, for example reading the Holy Quran. The direction to Kaabah is also known as *Qibla*.

A series of rites performed in Hajj and Umrah symbolise the lives of the Prophet Ibrahim *(pbuh)*[3], his second wife, Hajar and their son, Ismail thousands of years back [204]. The definition of Hajj and Umrah are described as follows:

Hajj *Hajj means visiting Kaabah to perform a series of rites accordingly [202] within a six-day period [205]. The six days period is from 8th Dhu'l-Hijjah to 13th Dhu'l-Hijjah (that is, the last month of Islamic lunar calendar). The rituals of Hajj can be finished during the five days [206] that start from 9th Dhu'l-Hijjah. However, the normal period to begin the pilgrimage is from 8th Dhu'l-Hijjah.*

[1] or Kaaba or Ka'aba or Ka'bah
[2] or Masjid al-Haram
[3] stands for peace be upon him

Umrah *Umrah can be defined as visiting Kaabah to perform a series of rites accordingly any time throughout the year [207].*

Figure 3.1 also illustrates a situation when a lot of Muslims are gathering in Masjidil Haram. The photo shows pilgrims performing Tawaf (that is, walking around Kaabah – see Section 3.2.3). Regardless of country and ethnic group, every year many Muslims manage to assemble at Makkah simultaneously, in particular during the Hajj period. Hajj, therefore, is considered as one of the largest gatherings of people in the world. Also, this indicates the unity of Islamic brotherhood and sisterhood worldwide, although Hajj or even Umrah is one of Muslims' obedience expressions to God [208]. The Arabic word of God is *Allah (swt)*[4] [202, 209]. However, due to the mass of people gathered at the same time, the safety of Hajj pilgrims is widely promoted and prioritised; for example, pilgrims are encouraged to 1) perform rituals correctly, 2) choose an appropriate time to do some rituals due to their current health and physical condition, and the situation in Masjidil Haram and 3) move in groups.

Masjidil Haram can accommodate approximately 800 thousand pilgrims simultaneously [210]. This number is expected to increase to around two million once the current expansion project has finished [211, 212]. Buildings such as hotels, restaurants and shops have been developed around Masjidil Haram to provide every service to pilgrims just in walking distance.

3.2.2 Differences between Hajj and Umrah

Hajj and Umrah are a journey to the same place in Makkah. However, they are different in some aspects (Table 3.1). On the one hand, Hajj is called a major pilgrimage which is compulsory to Muslims provided they are healthy and can afford to do it [202]. Muslims can perform Hajj as much as they like however performing it once is enough in their lifetime. According to the history of Makkah, Hajj was declared as one out of five Islamic pillars by Prophet Muhammad *(saw)*[5] when he ruled Makkah. Hajj moreover can only be carried out within a six days period that is from 8^{th} Dhu'l-Hijjah to 13^{th} Dhu'l-Hijjah [205]. From the latest Hajj period (9^{th} to 14^{th} September 2016), the number of pilgrims who carried out Hajj was 1.8 million [213]. This number, however, was considered the smallest of the past 10 years [214].

On the other hand, Umrah is known as a minor pilgrimage [205]. Umrah is optional to Muslims, but they are highly advised to perform it if they can afford it [207]. Although Umrah was introduced before the government of Prophet Muhammad *(saw)*, Muslims are still recommended to carry it out. In contrast to Hajj, Umrah can be performed any time throughout the year [207]. Based on the latest Umrah period, from the end of October 2015 to early April 2016, the number of pilgrims who performed Umrah was 3.7 million [215].

[4] stands for Subhanahu Wa Ta'Ala that means All praises for him
[5] stands for Sallallahu Alaihi Wasallam that means God's peace and blessing upon him

Table 3.1: Differences between Hajj and Umrah

	Hajj	**Umrah**
Another name	Major pilgrimage	Minor or lesser pilgrimage
Ritual enforcement	Must be performed by Muslims who are healthy and can afford to do it	Optional but highly suggested
When it has been performed the first time	During the government of Prophet Muhammad *(saw)*	Before the government of Prophet Muhammad *(saw)*
When it can be performed	Six days period from 8^{th} Dhu'l-Hijjah to 13^{th} Dhu'l-Hijjah	Any time
Number of pilgrims during the latest pilgrimage period	1.8 million	3.7 million

3.2.3 Essential Rituals in Hajj and Umrah

To complete Hajj or Umrah, pilgrims must perform several essential rituals (*Rukun*) [216]. If an essential ritual is not carried out, Hajj or Umrah is considered invalid. In Hajj, pilgrims must perform six essential rituals [216] whereas, in Umrah, pilgrims must carry out five only [217] (Table 3.2). Both Hajj and Umrah pilgrims carry out two essential rituals that are the same, viz. Tawaf and Sa'ie [216, 217, 205]. These rituals are defined as follows:

Tawaf *Tawaf refers to walking counter-clockwise seven times around Kaabah. The area around Kaabah is called Mataf.*

Sa'ie *Sa'ie means travelling back and forth seven times between two hills called Safa and Marwah in Mas'a. Mas'a is a place to perform Sa'ie which is also located in Masjidil Haram.*

Although Hajj and Umrah have the same essential rituals, there are a few rituals which are slightly different, as well as Wuquf that is only done by Hajj pilgrims. In Hajj, pilgrims must be in a state of Hajj Ihram intention whereas, in Umrah, pilgrims must be in a state of Umrah Ihram intention. Ihram and Wuquf are defined as below:

Ihram *Ihram is a special state of ritual purity entered into by making a statement of intention [216, 217] that is done according to place and time or called Miqat in the Arabic language [218, 219, 205]. In this state, pilgrims must also wear special garments, especially men, which are also called Ihram. For men, it consists of two pieces of white sheet, however, for women, it is same as required by Islam that covers all parts of the body except face and hands [216]. The clothes are recommended in white colour. Pilgrims moreover must obey required regulations [220]. In other words, Ihram is a practical intention to begin Hajj or Umrah.*

Wuquf *Wuquf is understood to mean staying in Arafah, a desert about 20 km from Makkah [203] any time from the midday of the 9th Dhu'l-Hijjah to the dawn of the 10th Dhu'l-Hijjah [216].*

Pilgrims also must cut at least three hairs on their head in the specified time. For Hajj, it must be done at night of 10th Dhu'l-Hijjah [216], however, for Umrah, pilgrims must do it after performing Sa'ie [217]. Regarding gender, men are encouraged to shave all their hair off, whereas women just need to cut one inch of their hair, from any part of their head. Finally, Hajj pilgrims must maintain the sequence in performing most of the essential rituals [216]. By contrast, in Umrah, pilgrims are obliged to maintain the sequence in performing all essential rituals [217].

Table 3.2: Essential rituals in Hajj and Umrah

Hajj	**Umrah**
In a state of Hajj Ihram	In a state of Umrah Ihram
Wuquf	–
Tawaf	
Sa'ie	
Cutting hair on head at night of 10th Dhu'l-Hijjah	Cutting hair on head after performing Sa'ie
Maintain the sequence in performing most of the essential rituals	Maintain the sequence in performing all essential rituals

3.3 Sa'ie - An Essential Ritual in Hajj and Umrah

This section thoroughly discusses the Sa'ie ritual which is the case study of the PhD research, in particular, the experiment described in Chapter 5. Also, the ritual is essential in both Hajj and Umrah. That is, without it, Hajj or Umrah becomes invalid (see Section 3.2.3). This section first explains about Sa'ie. It then outlines all procedures to perform the ritual. Finally, it illustrates the main features in Mas'a and Masjidil Haram that are reference points for pilgrims to perform Sa'ie.

3.3.1 Introduction to Sa'ie

The Sa'ie ritual (Figure 3.2) is the one considered in the PhD research. The ground level of Mas'a was transformed into a virtual environment, and it was merged with game elements to teach how to perform Sa'ie correctly (see Chapter 5).

Safa, on the south and Marwah, on the north, both are located in Mas'a. Hajj and Umrah pilgrims used to travel between these two hills in an open area, however nowadays Mas'a can be accessed in an air-conditioned building.

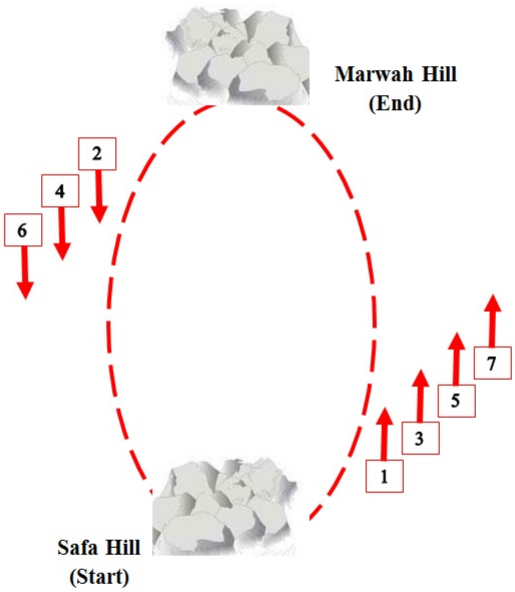


Figure 3.2: The flow of Sa'ie

3.3.2 Procedures when Performing Sa'ie

Given that Sa'ie is one of the essential rituals of Hajj and Umrah, pilgrims, therefore, must perform the procedures of Sa'ie correctly. The procedures of Sa'ie can be done by completing a series of actions which are divided into two categories, namely Conditions and Options (or *Sunnah* in the Arabic language) [216]. These two types are defined below:

Conditions *Conditions are necessary actions which the validity of Sa'ie depends on. Sa'ie becomes invalid if pilgrims do not carry out at least one action of the Condition.*

Options *Options are actions which are suggested to perform. In contrast to Conditions, Sa'ie is still valid despite not performing all actions of the Options. However, pilgrims are highly recommended to carry out an action of the Options to get more rewards from God.*

3.3.2.1 Conditions of Sa'ie

Pilgrims must perform all actions of the Conditions whether it is before or during Sa'ie [216] (Table 3.3). Before doing Sa'ie, pilgrims must do Tawaf first. They also must have a sincere intention. The Arabic word is *Niyyat*. It is sufficient enough if the intention is the thought in one's mind. Pilgrims must keep the intention of performing Sa'ie until the end of Sa'ie. During Sa'ie, pilgrims must begin from Safa and finish at Marwah, and they must reach at least the foot of Safa hill and Marwah hill. They also must cover the lane between Safa and Marwah, not anywhere else. As explained before, pilgrims must travel back and forth seven times. The first round begins from Safa and ends with Marwah, the second round starts from Marwah and ends with Safa and so on until the final round (7th round).

Table 3.3: Conditions before and during Sa'ie

Actions of Conditions	
Before Sa'ie	**During Sa'ie**
Do Tawaf first and followed by Sa'ie	Begin from Safa and end at Marwah
	Reach the foot of Safa and Marwah
	Cover the lane between Safa and Marwah
	Complete seven rounds
Keep the intention of doing Sa'ie until the end	

3.3.2.2 Options of Sa'ie

Likewise, actions of the Options are also performed before and during Sa'ie [216] (Table 3.4). Pilgrims are recommended to enter Mas'a through a door namely Babussafa from Mataf, a place to carry out Tawaf. Before performing Sa'ie, pilgrims are also suggested to be in a state of ritual ablution. The Arabic word is *Wudhu*. The ritual ablution is the same washing Muslims do before they perform other rituals such as prayer. Pilgrims are suggested to be in the state of ritual ablution until the end of Sa'ie.

Pilgrims are suggested to carry out Sa'ie on foot. However, they are allowed to ride, for example using a wheelchair. For men, they are advised to carry out two actions of the Options such as go over the hills of Safa and Marwah and perform Ramal in the specified area. The action of Ramal is defined as follows:

Ramal *Ramal refers to walking briskly in the space between the first and last green light (see Figure 3.5 for more details).*

Also, pilgrims are suggested to look towards the Kaabah when they arrive at Safa hill and Marwah hill, and then say Takbir and make Du'a. They are also recommended to perform Muwalat. The terms Takbir, Du'a and Muwalat are defined as follows:

Takbir *Takbir is understood to mean God is the greatest.*

Du'a *Du'a can be defined as a prayer of supplication to God.*

Muwalat *Muwalat refers to be persistent in completing seven rounds.*

3.3.2.3 Additional conditions for women

In order to perform Hajj or Umrah, Muslim women must follow two additional actions of Conditions [202, 207] (Table 3.5). As the Sa'ie ritual is a part of Hajj and Umrah, these two actions are automatically applied to women. The first action is that women are obliged to ask permission from their husband or their Wali. They must also be accompanied by their husband or their Mahram or a group of trusted woman. Wali and Mahram are described as follows:

Table 3.4: Options before and during Sa'ie

Actions of Options	
Before Sa'ie	**During Sa'ie**
Go to Mas'a through a door called Babussafa	Perform on foot, but riding is permissible
	Go over the hills of Safa and Marwah (Men only)
	Look towards the Kaabah at Safa hill and Marwah hill, and say Takbir and make Du'a
	Carry out Ramal in green lights area (Men only)
	Perform Muwalat
Keep being in the state of ritual ablution until the end	

Wali *Wali can be defined as someone who has guardianship over somebody else.*

Mahram *Mahram refers to a male family member whom a Muslim woman cannot marry such as sons in law and grandchildren [221].*

Table 3.5: Additional Conditions for women

Additional Conditions for female Hajj and Umrah pilgrims	
Before	Ask permission from their husband or their Wali
During	Accompanied by their husband or their Mahram or a group of trusted women

3.3.3 Mas'a, a Place to Perform Sa'ie

Mas'a is located in Masjidil Haram where it is used to perform Sa'ie [203]. It consists of five levels (Figure 3.3). The five levels are basement, ground, first, second and rooftop or called *Sutoh* in the Arabic language. The rock remains in the basement and ground level of Safa and Marwah hill. However, on the ground level of Marwah hill, the rock is flat. The first and second level were built by the Saudi Arabian government to accommodate many pilgrims to perform Sa'ie concurrently. In these two levels, there is an open circle space at the area of Safa and Marwah hills. It allows pilgrims to see the rock of Safa and Marwah hill from these two levels. At the rooftop level, there are two domes of mosque showing the location of Safa and Marwah hill.

When performing Sa'ie, several features in Masjidil Haram, in particular, Mas'a are used as reference points such as the hill of Safa, the hill of Marwah, green lights area, travel lanes for disabled and non-disabled pilgrims and Kaabah. Figure 3.4 and 3.5 illustrate the location of these main features.

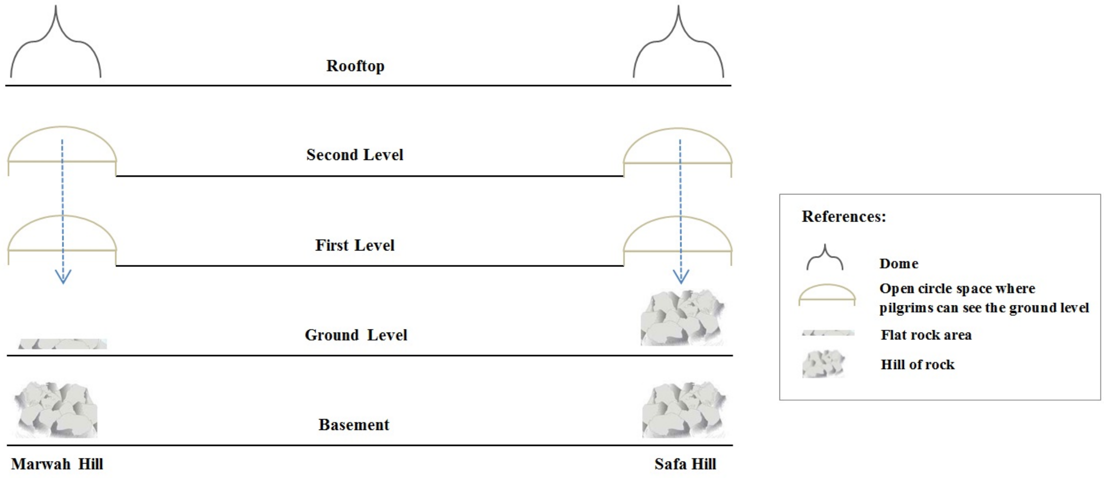


Figure 3.3: Levels in Mas’a

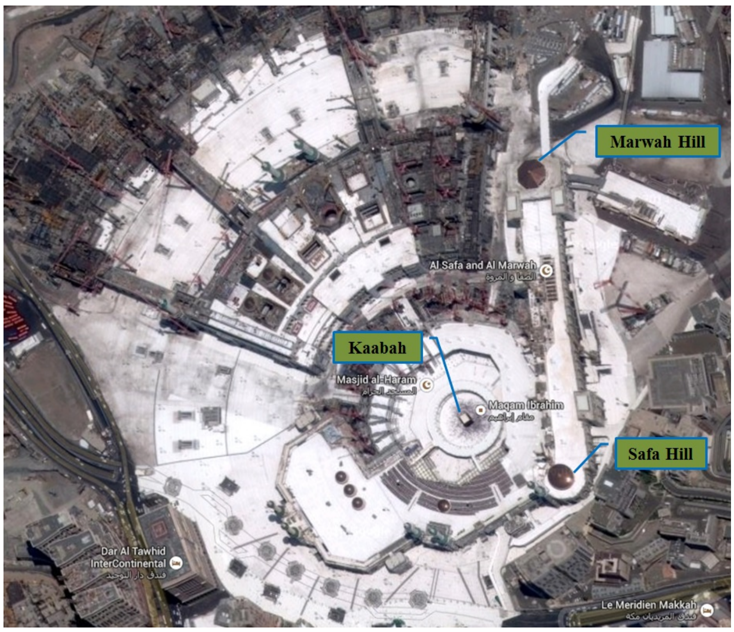


Figure 3.4: An aerial view of the location of Kaabah and hills

Figure 3.4 shows the location of Kaabah, Safa hill and Marwah hill from the top view. In Figure 3.5 some features in Mas’a are presented such as Safa hill, Marwah hill, green lights area and travel lanes for disabled and non-disabled pilgrims. All these features influence Sa’ie as explained below [217]:

1. It indicates the location of Safa and Marwah in Mas’a, Masjidil Haram. Also, it illustrates the route of Sa’ie which begins from Safa and ends at Marwah.
2. To complete Sa’ie, pilgrims must travel back and forth seven times between Safa and Marwah hills. Thus, they need to travel four times from Safa to Marwah and

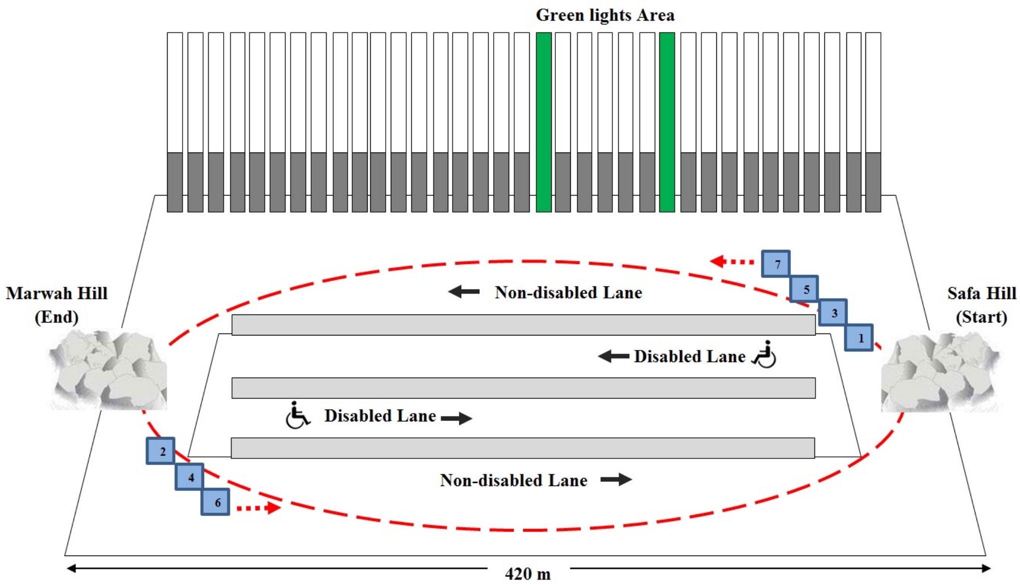


Figure 3.5: A side view of main features in Mas'a

three times from Marwah to Safa.

3. The distance between Safa and Marwah is approximately 420 metre which measn it is less than 3 kilometres to finish the entire ritual.
4. The travel lane to perform Sa'ie consists of two types which are a lane for disabled and elderly pilgrims, and a lane for non-disabled pilgrims. The travel lane in the middle of Mas'a was built for disabled and elderly pilgrims, and a larger area encircling this middle lane is the travel lane for non-disabled pilgrims.
5. There are green lights which were placed in both sections in Mas'a. Both sections in Mas'a refer to first, an area from Safa to Marwah and second, an area from Marwah to Safa. The space between the first and last green light is a place for male pilgrims to do Ramal (or walking briskly) (see Section 3.3.2.2).

3.3.3.1 Real images of main features in Mas'a

The figures in this section illustrate a real view of main features in Mas'a that were taken in February 2016.

Figure 3.6 shows Safa hill in Mas'a. The signpost of 'SAFA START' was placed closely to the hill to notify pilgrims about the start point of Sa'ie. Due to a large number of pilgrims as well as for their safety, the Saudi Arabian government built glass fences enclosing the rock of Safa hill. The same fences were also located around the rock of Safa and Marwah hill in the basement.

An environment of Safa hill in the first level is shown in Figure 3.7. There is an open circle space where pilgrims can see the rock of Safa hill on the ground level (Figure 3.7b).

Figure 3.6: Safa hill on the ground level of Mas'a

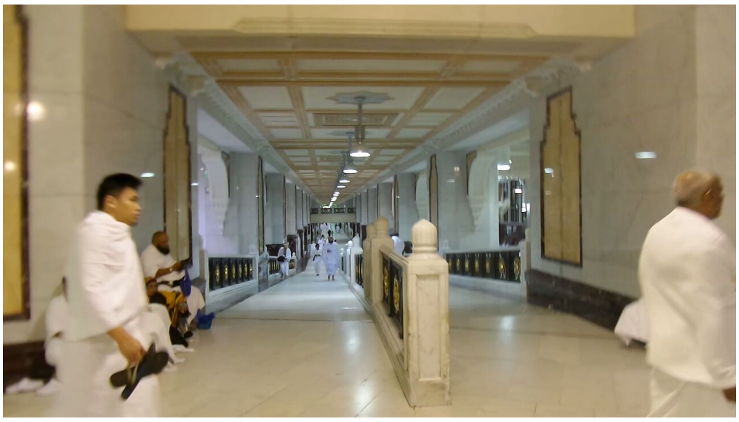
(a) Safa hill area

(b) An aerial view of the rock at Safa hill

Figure 3.7: The first level of Mas'a

There are two kinds of a travel lane in Mas'a such as the middle lane that is for disabled and elderly pilgrims (Figure 3.8 and 3.9a) and an area around the middle lane that is for non-disabled pilgrims (Figure 3.8 and 3.9b). The disabled or elderly pilgrims can be pushed while they are sitting down on their wheelchair (Figure 3.8). Normally, they are helped by their relative, or they can hire a helper provided by an authorised agency in Masjidil Haram.

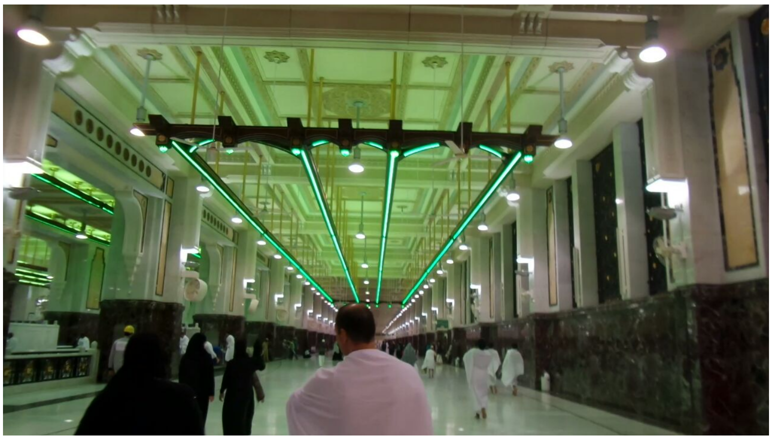
Figure 3.8: Travel lanes at Safa hill on the ground level



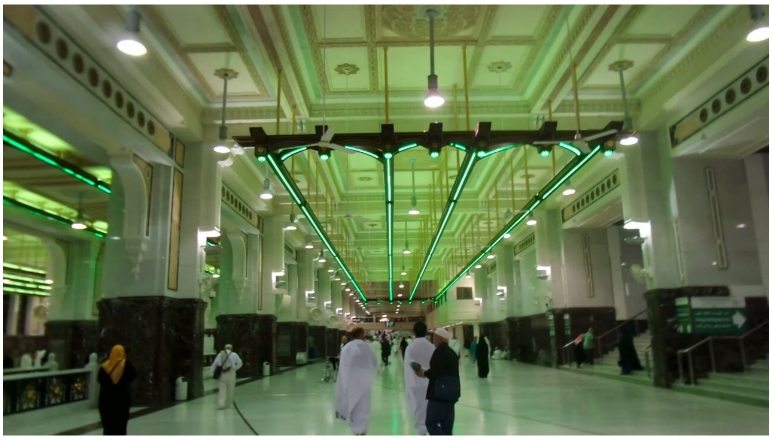
(a) Disabled lane

(b) Non-disabled lane

Figure 3.9: Travel lanes at Marwah hill on the ground level



(a) From Safa hill to Marwah hill

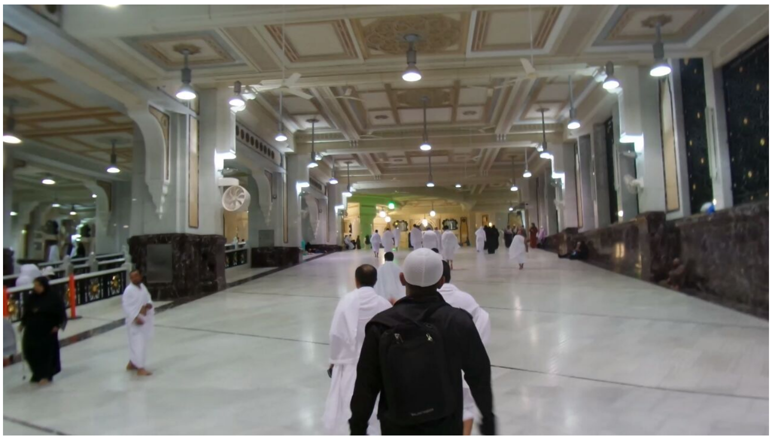


(b) From Marwah hill to Safa hill

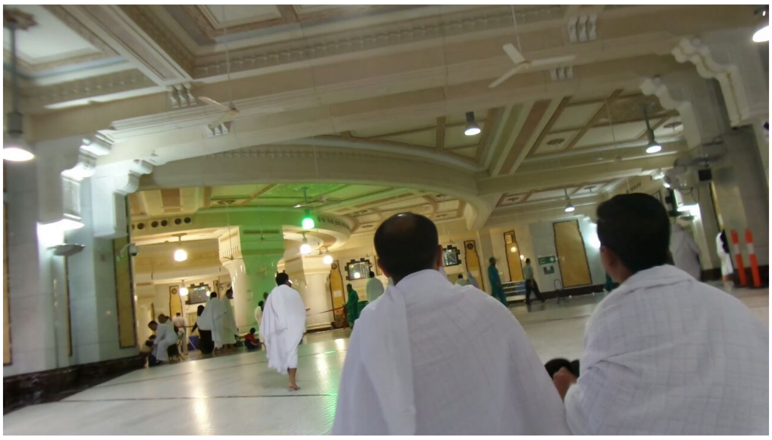
Figure 3.10: Green lights area on the ground level

The location of green lights area is shown in Figure 3.10. The green lights are located close to the ceiling so that all pilgrims can see it from far, in particular men to perform Ramal (or walking briskly). The first green light indicates the start point to walk faster and men start walking as usual after reaching the final green light. As shown in both figures, the green lights are located in both sections in Mas'a that is from Safa to Marwah and from Marwah to Safa and are also placed in the lane for disabled or elderly pilgrims. Figure 3.10b also indicates the stairs which connect Mas'a to Mataf, a place to perform Tawaf (or walking around Kaabah).

Figure 3.11 and 3.12 exhibit Marwah hill which is the end point of Sa'ie. Figure 3.11a shows the foot of Marwah hill. The rock at Marwah hill is not located in the middle of the hill (Figure 3.11b). However, the rock which is flat is located close to the wall or area to head back to Safa hill (Figure 3.12a). The last figure, Figure 3.12b shows a few signposts that indicate a direction to places such as Safa (start point of Sa'ie), Mataf (the area to perform Tawaf) and a temporary ring to perform Tawaf that was disassembled recently [222].



(a) The foot of Marwah hill



(b) Marwah hill

Figure 3.11: Scene 1 of Marwah hill on the ground level

3.4 Review Virtual Environments for Learning Hajj and Umrah

This section provides a literature survey from recent studies regarding learning Hajj and Umrah in virtual environments. First of all, it explains some reasons why pilgrims especially those that are not from Saudi Arabia require such training before performing real Hajj and Umrah in Makkah. This section then describes the conventional methods which are currently used in Malaysia to teach Hajj and Umrah pilgrims before going to Makkah. It also describes several attempts to transform Makkah and rituals of Hajj and Umrah into a virtual environment with the aim to provide a better medium for learning. In the end, a summary of this review is discussed.

3.4.1 Reasons to Learn before Performing in Real

Since a few years ago, the technology of virtual reality has been utilised to transform Masjidil Haram into digital form mainly to teach pilgrims to performing the ritual of

(a) Flat rock

(b) An area heading back to Safa hill

Figure 3.12: Scene 2 of Marwah hill on the ground level

Hajj and Umrah. To Muslims, Makkah is known as the holiest city in the world. It is located in Hejaz which is the west region of Saudi Arabia. However, it has been believed by some people as an undisclosed and mystical city due to its restriction to non-Muslims. Therefore, another purpose of transforming Masjidil Haram into a virtual environment is to illustrate an actual scenario of Makkah with the hope of reducing and subsequently, erasing the false impression of Makkah [205].

To billion of Muslims in the world, Hajj is unique and valuable because it resembles the history of Islam thousands of years ago and the obligation is at least to perform it once only in a lifetime [202]. They also believe that by performing Hajj correctly and sincerely, they will get special rewards from God. However, to certain Muslims, for instance, Muslims in Malaysia, the overall cost to perform Hajj is quite expensive. The Government of Malaysia, however, subsidise the trip. Moreover, Makkah is quite far, and the weather is totally different from their country. In the year 2006, the number of pilgrims who died because of poor preparation was about 243 pilgrims [205]. Other reasons that contribute to such incidents are the huge crowds, health problems, exhaustion, food and hygiene. Also, Hajj and Umrah consist of several rituals which are essential to carry out by every pilgrim. As both pilgrimages are complex, pilgrims are highly encouraged to have proper knowledge before arriving at Makkah, for example, procedures of each ritual and landmarks in Masjidil Haram. If pilgrims have sufficient knowledge, it can prevent them from making more mistakes when performing a ritual and also, avoid them from getting lost in particular, in overcrowded conditions which usually occurs during Hajj season.

For these reasons, a virtual environment that completely resembles Masjidil Haram and that provides a comprehensive method in learning the entire procedure of Hajj should be proposed and consistently improved to enhance users' knowledge and experience.

3.4.2 Conventional Methods

This section reports the current approach of learning Hajj and Umrah in Malaysia. However, in other countries such as Singapore and Iraq, they also provide such training course and material for their pilgrims. In Malaysia, before going to Makkah, pilgrims normally attend a few courses that are provided under Malaysian Pilgrim's Development Programme [223]. The courses are organised by Lembaga Tabung Haji, an organisation which is responsible for Hajj and Umrah pilgrims. The Hajj courses comprise four types which are Basic, Intensive, Special and Prime. In the Basic course, a classroom setting is used and is held at mosques around Malaysia. While the Intensive and Special courses emphasise on physical exercises of ritual that are held at an outdoor area. The same method is used in the Prime course. However, it gathers a large number of learners to imitate an actual scenario of Hajj in Makkah [224]. By organising such courses, Lembaga Tabung Haji aims to teach pilgrims the exact procedures of Hajj as well as to expose them to a real situation. Although four courses are provided to achieve the learning objectives, some Hajj pilgrims still struggle to understand and carry out a procedure of ritual [225].

Apart from that, Hajj and Umrah pilgrims usually gain information about rituals via conventional methods such as books, videos, images, classroom teaching and websites. Although the methods have been used for a long time, they show some flaws. In most cases, books and videos are used to teach pilgrims, but these materials are inadequate to provide knowledge in performing Hajj and Umrah correctly [226]. Also, the use of images of Makkah may illustrate a realistic situation, but some Hajj and Umrah learners cannot imagine an accurate and complete environment [227]. Typically, learning in a classroom is a right approach for direct discussion. However, it reduces the efficiency of knowledge delivery from an instructor to learners when it involves many learners at the same time [209]. Also, the previous studies have shown that classroom setting seems ineffective to understand some knowledge that requires imagination to understand it fully [22, 37]. To most people, websites are well-known as a quick platform to reach any information. However, the website describing Hajj presents information in 2D models only that are the same as books and images [228].

3.4.3 Modern Methods

The emergence of virtual reality technology has revealed a new method to learn Hajj and Umrah differently. Although the efforts are not widely used as in other areas such as medical and military, their attempts to overcome the weaknesses of a conventional learning method should be acknowledged and continued. A few attempts have been made to transform the entire procedure of Hajj and Umrah into a virtual environment, for example, the development of virtual training application for Tawaf and Sa'ie. In the following section, there is a review of Mataf simulation, the area for Tawaf as well as a review of learning Hajj and Umrah in virtual environments.

3.4.3.1 Mataf simulation

According to the latest statistic mentioned by Schneider et al. [205], more than two millions pilgrims came to Makkah recently to perform Hajj. To imitate the same scenario, several attempts have been made to develop a virtual Tawaf in Mataf with crowd simulation. For example, Sarmady et al. [229] coupled multi-agent based method with Repast J, a toolkit to develop a crowd simulation around Kaabah. The method was used to create crowd behaviours, however, in the current study, they implemented simple behaviours only. Narain et al. [230] presented a new variational constraint to simulate 25,000 pilgrims with various behaviours. It was also used to control collisions amongst agents in huge crowds. However, it detected local agents only and was unable to predict imminent collisions from remote agents.

Rahim et al. [224] used a new method calculating crowd simulation based on four corner points of Kaabah. The simulation located crowds in some places in Mataf and generated a circular movement of crowds around Kaabah. Curtis et al. [231, 232] built a simulation of 35,000 pilgrims moving without collision based on a combination of the finite state machine and agent-based algorithm. In their work, the machine created agents behaviours whereas the algorithm produced interaction amongst agents to avoid collisions while moving around Kaabah. Also, the simulation was tested according to agent age and gender, for example, young male and female, and old male and female. In the same year, Schneider et al. [205] proposed a multi-purpose framework of crowd simulation which derived from work of Curtis et al. [231]. The framework was used to study dense crowd motion regarding architectural changes and evacuation plans, and also to find solutions for logistic and organisational problems during Hajj.

The new formula created by Rahim et al. [224] became inefficient when the number of character reached 500. In contrast, the work developed by Narain et al. [230] and Curtis et al. [231] had potential to simulate thousands of pilgrims which followed certain behaviours while performing Tawaf. However, none of the applications focused on learning a complete procedure of Tawaf in a virtual environment.

3.4.3.2 Learning rituals in virtual environments

Due to weaknesses of supplementary materials provided to Malaysian Hajj pilgrims, Virtual Hajj (V-Hajj) was created by Yusoff et al. [226] as a new learning aid. In the V-Hajj, they integrated three components such as 3D visualisation, multimedia elements and persuasive design. The reason they employed a persuasive design in the V-Hajj was to persuade elders to use a computer in learning Hajj procedures. In their evaluation, they asked 60 participants to use the V-Hajj followed by answering Technology Acceptance Model (TAM) questionnaires. The results present that the V-Hajj was able to support the existing materials amongst young and elder learners. However, the V-Hajj was developed as a courseware-based application which can be categorised as a non-immersive virtual reality application.

Also, a study on the effectiveness of web-based simulation to teach Hajj procedures was done by Ziden and Rahman [233]. In their work, they compared two learning methods between presentation slide with the web simulation and presentation slide only. The former method was considered as an experimental group, and the latter was a control group. They recruited 80 secondary school students, 40 for each group. Before and after learning, they were asked to answer questions on pilgrimage topic to measure their learning achievement. The difference results indicate that the web simulation was a better approach of grasping the knowledge of Hajj consistently. Nevertheless, their work did not focus on full immersion as users interacted through a computer screen only.

To date, only one study has focused on learning Umrah in virtual environments. Rahim et al. [227] proposed five components to develop virtual Umrah application such as content and user profile. The components were also integrated with elements in the user-centred design. As their work was just a recommendation of the framework, thus no evaluation was made. Also, their work was as same as Ziden and Rahman [233] that proposed user interaction through a computer screen, suggesting that sense of engagement might decrease throughout the learning process.

Yasin et al. [234] created a model of Mataf to teach learners about the procedure of Tawaf. They emphasised on learning through an avatar and situated learning theory in their work. They moreover made it available on the web for users to learn the Tawaf anytime. The application was good because it provided current information while moving in the environment. For example, it notified users the current count of Tawaf cycles via a lap counter displayed on the top right corner. However, the application showed some weaknesses such as the text explaining the actions of Tawaf was not well-presented. It also did not provide feedback if learners acted wrongly, for example moving in the wrong direction (not anti-clockwise). As their work focused on virtual Mataf development only, therefore no evaluation was made.

Previously, Yasin et al. [209] proposed the same method to learn Sa'ie in the virtual environment of Mas'a. Up to this point, their work has been the only study which focused on the ritual of Sa'ie. 60 students were recruited to evaluate their virtual application. They then were divided into two groups, in particular, a group that learned Sa'ie through PowerPoint and a group that used the virtual application. After learning Sa'ie, they were asked to answer a set of spatial knowledge questionnaires. The results present that their virtual Sa'ie application was able to replace the conventional methods. However, their application had a few flaws. For example, there was no signpost showing Safa and Marwah. Instead, they just used a 2D map which was placed out of the simulation. Also, the application did not provide enough reference points to learn Sa'ie procedures correctly.

In short, the virtual Tawaf and Sa'ie application developed by Yasin et al. [234] and Yasin et al. [209] were the right attempts to transform the actual situation of Masjidil Haram into virtual environments. Using the web was an excellent idea to reach diverse learners at any time; however, the consistent accessibility was questionable. Although the concept of an avatar was introduced, learners looked around in the virtual environment as the third-person experience through a computer screen which was as similar study as Yusoff et al. [226], Ziden and Rahman [233] and Rahim et al. [227]. Therefore, learners cognitively translated the knowledge themselves and required some time to reflect on it. As a result, learners might not fully acquire the knowledge at the moment they used the applications.

Table 3.6 presents a summary of learning Hajj and Umrah according to the previous studies. The summary describes types of ritual learnt, visuals to experience and instruction modalities used while learning a ritual.

Table 3.6: Summary of Hajj and Umrah in virtual environments

Authors	**Ritual**	**Visual**	**Instruction Modalities**
TH Education Unit [223]	Hajj	Real	Companion
Yusoff et al. [225, 226]	Hajj	2D	Text
Ziden & Rahman [233]	Hajj	2D	Text, pictorial & companion
Rahim et al. [227]	Umrah	2D	Text & pictorial
Schneider et al. [205]	Tawaf	3D	*
Rahim et al. [224]	Tawaf	3D & 2D	Companion
Sarmady et al. [229], Narain et al. [230], Curtis et al. [231, 232]	Tawaf	2D	*
Yasin et al. [234]	Tawaf	2D	Text
Yasin et al. [209]	Sa'ie	2D	Pictorial

** Unknown instruction modality*

3.4.4 Review Summary

To summarise, virtual environments appear as an appropriate platform to overcome the flaws of conventional methods of learning Hajj and Umrah. Besides, some elements can be considered to improve ritual learning in virtual environments such as 1) development more engaging environment, 2) use apparent reference points, 3) clear instructions of ritual procedure, and 4) transfer of knowledge from virtual training to the real world, in particular, in an extended period.

3.5 End-of-chapter Summary

As Hajj and Umrah are made up by complex procedures and much information, it will be good to transform each ritual in a separate virtual environment, and an improved ritual-based virtual environment is highly welcomed. As such, the development of the Sa’ie application that focuses on learning issues mentioned in Section 3.4.4 is a right approach because it will indicate early and significant findings on how to clearly deliver ritual knowledge to learners in virtual environments.

Chapter 4

Study 1

Contents

This chapter describes an investigation on three of the issues which are relevant for navigation-based procedural learning such as the need for a full three-dimensional representation to learn and memorise a navigation procedure, instruction modalities and short-term memory. An experiment that required participants to navigate on a route based on instructions was considered investigating those issues. To investigate the representations, learning a navigation task using both Google Street View and a three-dimensional virtual environment simulating the same route in the real world was compared. Also, three kinds of instruction modalities such as reading text on paper, phone instructor and a direct companion were compared. Finally, the short-term transfer of knowledge after learning the task was tested.

4.1 Introduction

This section explains requirement analysis, background and aim, research hypotheses and terminology of the present study (Study 1).

4.1.1 Requirement Analysis

Several studies of learning Hajj and Umrah in virtual environments have been carried out, indicating that virtual environment might be a suitable platform to learn a procedure of rituals in Islam (see Chapter 3). However, some studies in the literature have not taught complete procedures, and also, have not provided full three-dimensional environments. Therefore, it is important to re-evaluate whether three-dimensional representations are suitable for procedural learning. After reviewing the current methods of training that indicate weaknesses (Table 4.1), an investigation on the effectiveness of instruction modality in learning can be considered.

In the study presented in this chapter, the potential of virtual reality as a medium to discover and learn a route in the real world was investigated. The study also explored whether there might be a better modality of giving instructions during route learning and navigation. Apart from that, it checked on an ability of human memory to instantly recall the knowledge, determining whether knowledge from previous navigation experiences remain in their memory for a short-term period.

4.1.2 Background and Aim

Google Street View is a popular feature of Google Maps as it provides street-level image data (360-degree panorama) that can be used for route planning and familiarise with a place before travelling [235]. Virtual environments, instead, are made of three-dimensional models of a real-world setting [53] and have been used as a reliable tool for learning and training [1]. While navigating, most of the information is usually gathered through a visual channel and integrated with other information, such as spatial and olfactory, but also by following given navigation instructions. Google Street View provides the visual information as a flat, two-dimensional photographic image, and the navigation is provided by jumping from one image location to another, no other sensorial information is provided. In virtual environments, the visual information is provided as the rendering of three-dimensional representations, and it is possible to have further spatial information coming from the environmental sound.

The navigation-based experiment involving two environments was conducted. The

Table 4.1: Existing training methods

Training Method	Authors	Main Feature(s)	Limitation(s)
Book/Text-based	Yusoff et al. [226]	Text and image	Inadequate knowledge
Classroom	Yasin et al. [209]	Instructions from teacher	The efficiency of knowledge delivery reduces, in particular when it involves many learners at the same time
	Van Wyk and De Villiers [22], Limniou et al. [37]		Ineffective to understand some knowledge that requires imagination
Web-based	Ministry of Hajj [228]	Text and 2D models	Insufficient information
Physical exercise	Lembaga Tabung Haji [223]	At an indoor area that resembles the actual setting, and with instructors	Some users still struggle to understand the procedure of rituals
Virtual reality	Yusoff et al. [226, 225], Rahim et al. [227], Ziden & Rahman [233]	Non-full 3D representation	Lack of immersion
	Yasin et al. [234], Yasin et al. [209]		Poor contents presentation

first environment was three-dimensional representations of a real-world route and the second was the route view as visualised in Google Street View. In both environments, participants were asked to learn a route and simultaneously travel to find an unknown destination using associated instructions. Two different routes were used, one in each environment. These two routes were located close to one of the University of Sheffield buildings in the UK. Regarding instructions, three modalities were used such as text on paper, phone instructor or a direct companion. Text on paper was a set of non-verbal instructions on paper that enquired participants to read it. While phone instructor and direct companion were instructed verbally by an instructor, the phone instructor was placed in a different room, and the direct companion was located just beside the participants. The learning objectives (LO) for this experiment are as follows:

After learning and navigating in the environment,

1. LO 1: The learner will be able to draw the routes on paper (Post-route recognition task)
2. LO 2: The learner will be able to identify and place real-world landmarks on paper (Landmarks recall and placement task)
3. LO 3: The learner will be able to walk the same routes in the real world (Real world navigation task).

4.1.3 Research Hypotheses

Given the literature review conducted in Chapter 2, three hypotheses were made as follows:

1. It is possible to learn a route in a virtual environment, at least as well as route learning in Google Street View
2. Using a direct companion (or direct collaborative learning) provides better instructions for route learning than text on paper and phone instructor
3. Learning a route in a virtual environment enhance short-term memory of landmark representations.

4.1.4 Terminology

This chapter focuses on visual representations and instruction modalities. Given the frequency with which specific terms related to them occur in what follows, in particular, in Section 4.2 to 4.5, the terms will be abbreviated as VE (plural: VEs) - virtual environment, GS - Google Street View, RW - real world, TP - text on paper, PI - phone instructor and DC - direct companion.

4.2 Visual Representations

In this section, visual representations are discussed such as route selection and environments for navigation task, and also the development of the VE.

4.2.1 Route Selection

This section describes how the routes finally were chosen and also, completely explains about Route 1 and Route 2, the two routes involved in the experiment.

4.2.1.1 History

At the first place, the idea was to compare navigation between VE and RW only and just use a route in any building of the University of Sheffield. Therefore, the task to look for a room in Sir Robert Hadfield Building, University of Sheffield was chosen. The building had a unique layout; therefore, it was believed that the navigation task was good enough. However, the idea was not used as it was found that a navigation comparison amongst VE, GS and RW using a road route was more interesting than the current idea. Also, there was a risk that GS was not able to present information in buildings.

Based on route planning in Google Maps, several routes close to the Kroto Research Institute, University of Sheffield were found, with different distance and walking time. The first two routes had a distance of 0.48 kilometre (or 0.3 miles) and walking time of 5 minutes, and another seven routes with a distance of 0.64 kilometre (or 0.4 miles) and walking time of 8 minutes. Also, Kroto Research Institute is one of University premises. It was chosen as a venue to conduct the experiment in order to comply with University Research Ethics rule that ensures the personal safety of participants. However, all routes were eliminated because the routes were far and would require a long time to finish the entire experiment. The routes were kept as it might be used in the next experiment, as the current plan just focused on an instruction modality that was TP.

The process of route searching in Google Maps was repeated. Finally, three routes were chosen, which had same distance and walking time. The distance was 0.32 kilometre (or 0.2 miles) and walking time of 4 minutes. The similarity was considered to ensure participants encountering approximate difficulties in VE, GS and RW. However, the plan of work changed again. The latest idea was to compare navigation between VE and GS, and then use the RW to recall the navigation in VE and GS. Also, a comparison amongst three instruction modalities (TP, PI and DC) was agreed to be executed in the same experiment. Of the three routes, therefore, only two were used that named as Route 1 and Route 2.

4.2.1.2 Route 1 and Route 2

(a) Starting point (b) Destination

Figure 4.1: The starting point and destination in Route 1

The starting point of Route 1 was 30 Regent St (Figure 4.1a). The destination was a computer shop called Universal Computers where was located at 1 St George's Close (Figure 4.1b). In Route 1, five streets were involved such as Regent St, Portobello, St George's Terrace, Brook Hill/B6539 and St George's Cl.

For Route 2, the starting point was 1 Newcastle St, and the destination was Flame Hardeners Limited (Figure 4.2). The destination was a surface and induction hardening company where was situated at 9 Bailey Ln. Route 2 also had five streets such as Newcastle St, Broad Ln/B6539, Rockingham St, Boden Ln and Bailey Ln.

The route to Universal Computers, the destination in Route 1 was navigated as follows: 1) head on Regent St, 2) slight left onto Portobello, 3) slight right onto St George's Terrace and head on, 4) turn left onto Brook Hill/B6539 and head on, 5) turn right onto St

(a) Starting point (b) Destination

Figure 4.2: The starting point and destination in Route 2

George's Cl, and 6) the destination, Universal Computers is on the left (Figure 4.3).

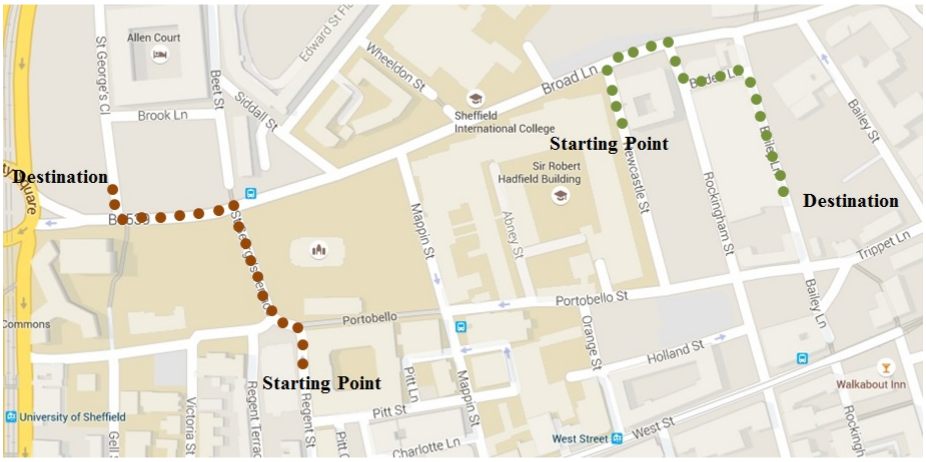


Figure 4.3: Directions of Route 1 (left) and Route 2 (right)

Figure 4.3 also shows the directions of Route 2 from Newcastle St. The directions of Route 2 were navigated as follows: 1) head on Newcastle St, 2) turn right onto Broad Ln/B6539 and head on, 3) turn right onto Rockingham St, 4) turn left onto Boden Ln and head on (Boden Ln is between Sheffield Window Centre and Silver Steel House), 5) turn right onto Bailey Ln and head on, and 6) the destination, Flame Hardeners Limited is on the left. A hint in direction four that indicates the exact location of Boden Ln was included in the instructions due to no signpost was provided in GS and even in the RW, either on the wall of buildings or the ground close to it.

Table 4.2 describes a summary of both routes. Both destinations according to navigation directions above were located on the left side.

Table 4.2: Concise information of Route 1 and Route 2

	Route 1	Route 2
Distance	0.2 miles = 0.32 kilometers	
Walking time	4 minutes	
Destination	Universal Computers, 1 St George's Cl	Flame Hardeners Limited, 9 Bailey Ln
Destination position	Left	
Starting point	30 Regent St	1 Newcastle St
Streets used	Regent St Portobello St George's Terrace Brook Hill/B6539 St George's Cl	Newcastle St Broad Ln/B6539 Rockingham St Boden Ln Bailey Ln

4.2.2 Navigation Environments

Route 1 was chosen to be translated and used for VE navigation whereas Route 2 was utilised in the GS, where participants perceived 360-degree panoramic views of streets, to perform the navigation task. Route 1 was chosen to be translated because its condition in the RW was easier for photo taking that was used in the VE development, instead of Route 2. For GS navigation, participants were asked to use four arrow keys on the keyboard to move in the panoramic scenes. The UP key was used to go forward, the DOWN key to go backwards, and the RIGHT and LEFT keys were for right and left turn respectively.

4.2.3 How the Virtual Environment Was Developed

For the VE of Route 1, it was developed through two stages. The first stage was using SketchUp only and the second stage was a combination between SketchUp and the game engine Unity. Both stages used the same machine that had the following specifications: 1) Operating system: Windows 7 Enterprise 64-bit; 2) Processor: Intel®Core™i5-3350P CPU @ 3.10 GHz 3.30 GHz; 3) Memory: 8192 MB RAM; 4) Graphic card: NVIDIA GeForce GTX 650 Ti with total memory of 4038 MB; and 5) Hard-disk space: 800 GB free. These two stages are described in the next sections.

4.2.3.1 First stage of the virtual environment development - SketchUp

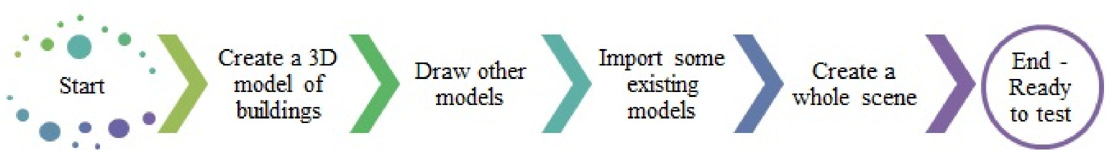


Figure 4.4: Four phases of the VE development in SketchUp

SketchUp Pro was used to create 3D models in the VE. The development of Route 1 in SketchUp was divided into four phases (Figure 4.4). The first step was to create the buildings in Route 1 such as Innovation Centre and housing area.

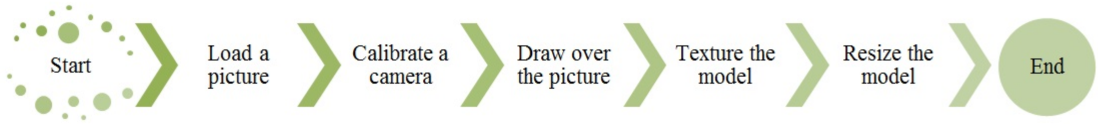


Figure 4.5: Steps in the Match Photo technique

(a) USE

(b) Innovation Centre

Figure 4.6: Buildings created from Match Photo technique

It was found that the most suitable technique to draw buildings in SketchUp was Match Photo. It applies a RW scale from photos and also uses the same photos to texture the model. Figure 4.5 shows steps of the Match Photo technique and Figure 4.6 presents the buildings created from the technique, for example, USE (Figure 4.6a) and Innovation Centre (Figure 4.6b).

Figure 4.7: Steps of creating the whole scene

The next phase was to draw other models such as sign posts and fence by using basic SketchUp techniques. The rest of the features, for instance, plants and traffic light were imported from 3D Warehouse[1]. The whole scene to combine all 3D models was created in the Scene window (Figure 4.7). Finally, the VE of Route 1 was finished. It was tested using Walk[2] tool in SketchUp.

Unfortunately, the VE of Route 1 did not work well due to a few problems, for example, few models created using Match Photo experienced some textures missing although

[1]https://3dwarehouse.sketchup.com/?hl=en
[2]https://help.sketchup.com/en/article/3000145

the rendering process finished. A few solutions to overcome the problems were tried, such as testing the VE of Route 1 on other machines and reducing the size of the models. However, the VE of Route 1 still experienced the same problems. Therefore, the development of Route 1 VE in SketchUp stopped, and Unity was chosen to replace it. However, all 3D models in SketchUp were going to be used in Unity.

4.2.3.2 Second stage of the virtual environment development - SketchUp and Unity

Unity[3] was used to create the VE of Route 1. The Unity version that was installed in the machine was 4.6.1f1. 3D model is saved individually as Kaydara (FBX) file in SketchUp and is exported into Assets folder in Unity.

There were two main elements at the early stage of development in Unity. The first element was the ground bases. The bases were categorised into two types, such as the base that contained streets with pavement and the base for each building. The second element to be focused on was the navigation method in the game environment. Unlike SketchUp, Unity requires an object with a script to enable navigation in the environment. It was found that the most suitable method was using four arrow keys on the keyboard that was the same approach as in the GS navigation. A white arrow was then created in SketchUp and utilised for the navigation. Also, at all times, it located at foot level, indicated the current direction of movement.

Forty-one models of Route 1 were exported from SketchUp. Several steps were done to create the entire VE of Route 1 in Unity (Figure 4.8). Finally, the Unity application of VE of Route 1 was complete and ready to be tested (Figure 4.9). The test was done a few times including user testing and test on different machines.

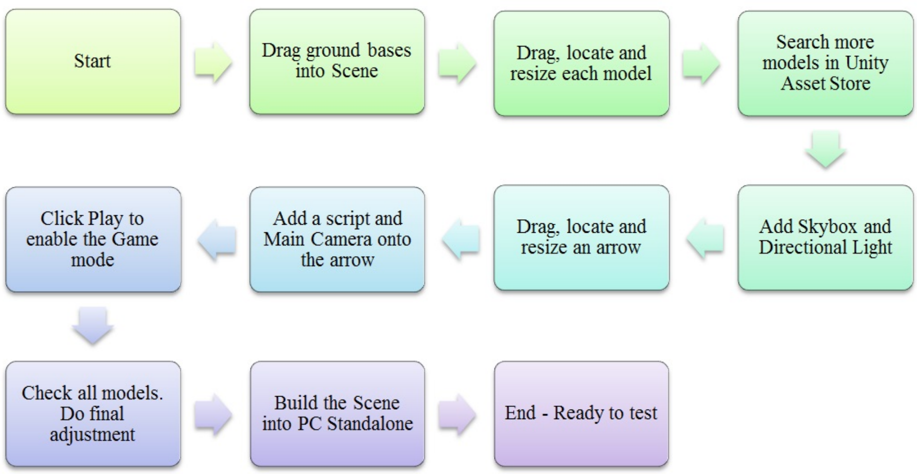


Figure 4.8: Steps of the VE development in Unity

[3]https://unity3d.com/

(a) Street of the starting point

(b) Destination

Figure 4.9: The VE of Route 1

4.3 Materials and Method

4.3.1 Participants

Thirty-six participants without any evident disability and able to walk without aid were recruited for the experiment via word of mouth and the volunteers mailing list. The number of women and men was equal (18 for each group - 50%) (Table 4.3). All participants, when asked in the consent form, declared that they did not have epilepsy and within the last 12 hours, they had not consumed alcohol, drugs or taken any prescription medication. These are common conditions that can alter the perception of VEs.

The average age of the participants was between 25 - 34 years old of which 4 participants (11.1%) fell in the 18 - 24 age category, most participants (27 people - 75%) were 25 - 34 age category and another 5 (13.9%) were 35 - 44 age category. Of the 36, only 1 participant (2.8%), the first language was English. The rest of 35 participants (97.2%), the first language was not English. However, they were all fluent in English and had English as the second language.

Thirty-one of them (86.1%) held a valid driving licence, and another 5 (13.9%) did not have a licence. Four participants (11.1%) stated that they used a satellite navigation (SatNav) system to drive every day, 10 (27.8%) used it once a week, 6 (16.7%) used it once a month, 12 participants (33.3%) declared that they seldom used a SatNav system, 3 participants (8.3%) never used it, and only 1 person (2.8%) stated that s/he never drove.

Table 4.3: Demographic background of participants

Demographic Item		***n***	**%**
Gender	Male	18	50
	Female	18	50
Age category (years old)	18 - 24	4	11.1
	25 - 34	27	75
	35 - 44	5	13.9
English as the first language	Yes	1	2.8
	No	35	97.2
Having a driving licence	Yes	31	86.1
	No	5	13.9
Frequency of using SatNav	Everyday	4	11.1
	Once a week	10	27.8
	Once a month	6	16.7
	Seldom	12	33.3
	Never	3	8.3
	Do not drive	1	2.8

4.3.2 Experiment Design

The experiment involved navigation in two environments (VE and GS), and three instruction modalities (TP, PI and DC). These variables, therefore, produced six combinations such as VE&TP, VE&PI, VE&DC, GS&TP, GS&PI and GS&DC. Also, every participant was asked to perform the task in both environments, however with different instruction modality (Table 4.4). Hence, the order of environment and instruction modality was counterbalanced. In the experiment, 18 participants navigated in VE first and another 18 navigated in GS first, and every set of design was done by six participants.

4.3.3 Data Collection, Scoring and Questionnaires

Experiment data were obtained in three sessions such as pre-, during and post- (Table 4.5). This section also discusses the questionnaires used in the experiment that were developed by referencing survey questions in published literature.

4.3.3.1 Pre-session

Background information
Participants were asked to answer some background information such as gender, age,

Table 4.4: Six sets of experiment design

	First navigation		Second navigation	
Set 1	VE	TP	GS	PI
Set 2	VE	PI	GS	DC
Set 3	VE	DC	GS	TP
Set 4	GS	PI	VE	TP
Set 5	GS	DC	VE	PI
Set 6	GS	TP	VE	DC

VE = Virtual environment, GS = Google Street View, TP = Text on paper, PI = Phone instructor, DC = Direct companion

the first language and driving routines such as holding a valid driving license and use of SatNav system for driving. This background information was collected to check its relationship with navigation and learning in VE and GS.

Spatial and navigational abilities
Participants also rated their spatial and navigational abilities that measured their cognition and skills on the environmental knowledge [236]. Of 27 questions provided by Hegarty et al. [236], only seven questions were used because these questions were more relevant to the navigation task than other questions. Two questions were slightly changed to better fit the scope of study, for example, 'I am very good at giving directions' was modified to 'I am very good at following a sequence of instructions', and 'I very easily get lost in an unfamiliar building' was amended to 'I very easily get lost in an unfamiliar area'. The other five questions were 'I do confuse right and left much', 'My "sense of direction" is very good', 'I have a poor memory for where I left things', 'I can usually remember a new route after I have travelled it only once', and 'I try to remember details of the landscape (objects) when traveling in a new area'. The score ranges on a 5 point Likert Scale, in which 1 is 'strongly disagree' and 5 is 'strongly agree'.

Immersive tendency
Participants' tendencies to experience presence were also examined. Of 29 questions provided in the Immersive Tendency Questionnaire [237], only seven questions which were appropriate to the context of the study were used. The questions were similarly included in the questionnaire. The score of six questions range from 1 to 5. For example, 'How easily can you switch your attention from the task in which you are currently involved to a new task?' and the score 1 is 'not easily' and 5 is 'very easily', 'To what extent have you dwelled on personal problems in the last 48 hours?' and the score 1 is 'not at all' and 5 is 'very much', 'How well do you concentrate on enjoyable activities?' and 'How well do you concentrate on disagreeable tasks?', and for these two questions, the score 1 is 'not well' and 5 is 'very well', and 'Do you ever avoid carnival or fairground rides because they are too scary?' and 'Do you ever become so involved in doing something that you lose all track of time?', and for both questions, the score 1 is 'rarely' and 5 is 'frequently'. Another question: 'Have you ever gotten excited during a chase or fight scene on TV or in the movies?', asked participants to answer 'yes' or 'no'.

Table 4.5: Experiment sessions

Session	Tasks	Time allocation	Data collection	Tools
Pre	Experiment formalities	**5 min**	–	Details sheet and consent form
	Questionnaire and drawing	4 min (4 min x *2 tasks* = **8 min**)	Background information, spatial and navigational abilities, immersive tendency, *mood and pre-route recognition*	Online questionnaire and map
During	Navigation in VE and GS with assigned instructions	10 min (10 min x *2 tasks* = **20 min**)	*Time, video and conversation*	Stopwatch, Microsoft Expression Encoder 4 Screen Capture, Sound Recorder and Smart Voice Recorder
Post	Questionnaire and drawing	5 min (5 min x *2 tasks* = **10 min**)	*Mood, post-route recognition, landmarks recall and placement, navigation experience and presence*	Online questionnaire and map
	Navigation in RW (RW-VE and RW-GS)	15 min (15 min x *2 tasks* = **30 min**)	*Time and route*	RunKeeper and Global Positioning System
	Questionnaire	**2 min**	Navigation comparison and comments	Online questionnaire

2 tasks = 2 navigation tasks

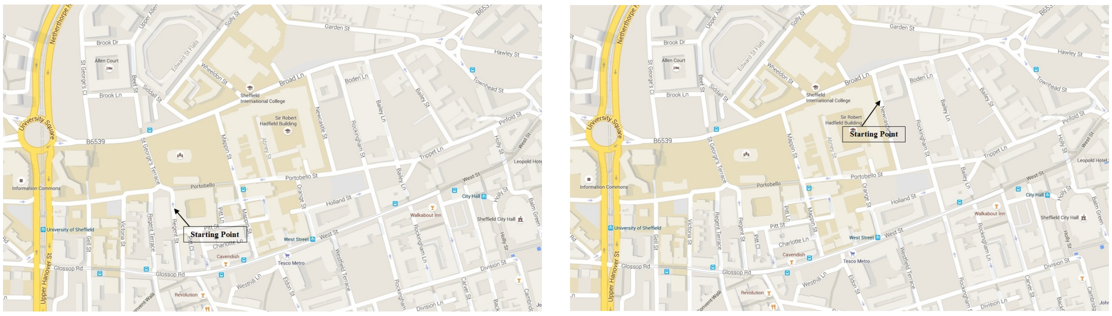
Moods

Participants were then asked about their current moods. A reduced version of the Brief Mood Introspection Scale (BMIS) [238, 239] was used that asked them whether they felt 'happy', 'tired' or 'fed up'. As in the original questionnaire, the score of 'happy' mood ranges from 1 to 4, in which 1 is 'I definitely do not feel ... ' and 4 is 'I definitely feel ...'. A similar pattern was used to enquire about their tiredness and frustration levels. Participants were also asked to score their 'overall mood'; the score ranges from 1 to 4, in which 1 is 'very unpleasant' and 4 is 'very pleasant'.

Pre-route recognition

Participants performed the pre-route recognition task to establish the baseline knowledge before navigation. The task asked participants whether they knew the location of the destination they were going to navigate to. If they knew, they were asked to draw a route on the map taken from Google Maps (Figure 4.10) and also to mark the location of the destination. This task was designed by referencing the task of 'Sketch Maps' from Suma et al. [240]. 'Sketch Maps' however used blank sheets of paper and asked participants to sketch top-down maps of the environment.

For scoring elements, a score of one was given if they drew a route from the start point indicated on the map and they located the destination at the correct place. A score of



(a) VE map (b) GS map

Figure 4.10: Map used in the pre-route recognition task

zero was given if they located the destination wrongly.

4.3.3.2 During session (Virtual environment and Google Street View navigation)

Navigation time
The time if took participants to finish the navigation was recorded. It stopped due to the following reasons, as soon as: 1) they reached the destination (that is the target point was in view on the computer screen), 2) the allocated time (10 minutes) was finished, and 3) they asked to stop the navigation as they gave up.

Navigation video
When performing the task, their navigation was also video recorded. The video was used to study participants' behaviour while navigating in both environments such as reasons they put more effort and took longer time than others in order to complete the navigation, rationale why they missed some streets and target destination, advantages and disadvantages of both environments, and also behaviour similarity from both VE and GS navigations.

Conversation
For navigation instructed by the phone instructor or the direct companion, the entire conversation was recorded to determine the number of questions and types of questions that participants asked the instructor while carrying out the task. Both conversations were recorded by instructors (PI and DC). As it involved the audio recording, prior consent from participants was given, and only the conversation of participants who gave their consent was recorded.

4.3.3.3 Post-session

Moods
Participants were asked again about their current moods. The same questions as in Section 4.3.3.1 were used.

Post-route recognition
Also, participants performed a post-route recognition task that asked them to draw the

route they had navigated and to mark the start point and the destination on the map. The same maps in Figure 4.10 were used for VE and GS. However, the maps had no sign of start point to measure participants' overall knowledge acquisition from navigation.

The route drawing was scored based on five elements: the correct identification of the starting point (1 point) and destination (1 point), recurrence of erasing lines (1 point for no hesitation, 0.5 for up to three lines, a score of zero for more than three lines), if they drew all five streets of the route (1 point for each street), and if they drew exactly the route as taught without mistakes also they would be awarded one, if they had one to three mistakes 0.5 and for four or more mistakes they would be awarded zero. The maximum score achievable was nine.

Landmarks recall and placement
To also test the knowledge gained from navigation, participants were asked to do landmarks recall and placement task. These two tasks were also taken from Suma et al. [240]. In the work of Suma et al. [240], participants were asked to list as many objects as they could remember from the environment. However, in the current study, the objects were only limited to landmarks they had seen during navigation and participants were asked to list it on the computer screen as a part of the online questionnaire, instead of on a sheet of paper. Landmarks were divided into three categories as follows: 1) building, 2) sign such as traffic light and signpost, and 3) field such as garden and car park. The landmarks were counted, and one point was assigned for each one mentioned.

For placement task, Suma et al. [240] asked participants to place objects on a map based on a list of objects they gave, whereas, in the current study, participants were asked to place the landmarks they had recalled previously. They placed the landmarks on the same map they used for post-route recognition task. The map then was examined to check how correct they placed the landmarks in which a score of one was given if they marked all landmarks they had recalled correctly; a score of the number of landmarks placed correctly was divided by the total of landmarks recalled, was given if only some landmarks were marked, and a score of zero was given if no landmark was indicated.

Navigation experience
Also, participants were asked to evaluate their navigation experience. Of nine questions developed by Ruddle et al. [72], only two questions were taken to avoid lengthy questionnaire and were also modified to fit the study scope better. The score ranges from 1 to 5. Instead of 'How interesting was your interaction with the virtual environment?', it was changed to 'How interesting was your navigation in the virtual environment (or Google Street View)?' and the score 1 is 'very boring' and 5 is 'very interesting'. To better understand the way the learning objectives were presented, participants were asked whether the signposts containing the road name were 'easy' to find and whether the instruction modality was 'easy' to follow. The question of 'Was it easy for you to become "absorbed" in the virtual environment?' was modified to 'Was it easy to find

the sign of street you looked for in the virtual environment (or Google Street View)?' and 'Was it easy to navigate in the virtual environment (or Google Street View) by using this type of instruction?'. Both questions have the same score, in which 1 is 'very difficult' and 5 was 'very easy'. For GS, they were asked where they frequently found the street name during navigation, whether on the street that superimposed by GS or on the signpost that was same in the RW. This question was asked to check users' preference of seeing signposts when navigating in GS.

Presence
Moreover, a reduced version of the Presence Questionnaire [237] was used to enquire about presence during navigation. Of 32, seven questions which were the most relevant to the study scope were included without any change. The score of all questions ranges from 1 to 5. For instance, 'How much did the visual aspects of the environment involve you?', 'How much did your experiences in the virtual environment seem consistent with your real-world experiences?' and 'Were you involved in the experimental task to the extent that you lost track of time?', and for these three questions, the score 1 is 'not at all' and 5 is 'very much', 'How completely were you able to actively search the environment using vision?' and the score 1 is 'not at all' and 5 is 'completely', 'How well could you move in the virtual environment?' and the score 1 is 'not well' and 5 is 'very well', 'How distracting was the control mechanism?' and the score 1 is 'not distracting' and 5 is 'very distracting', and the final question was 'How much delay did you experience between your actions and expected outcomes?' and the score 1 is 'none' and 5 is 'a lot'.

Real world navigation time and route
For RW navigation, time and route were tracked by RunKeeper application in the mobile phone. Also, it stopped due to the same reasons as navigation in VE and GS.

Navigation comparison and comments
As participants experienced navigating in both environments, they were asked to compare which environment was more interesting to do the navigation task. Lastly, participants were also provided with a free text comment section.

4.3.4 Software and Hardware

Two sessions of the experiment were run concurrently in the same room named Reflex Studio in Kroto Research Institute (Figure 4.11), some hardware, therefore, was provided in two sets. For instance, two Dell laptops that had a good connection to the web were used to run the online questionnaire (i.e. Google Docs) and were placed on two different desks such as Desk 1 and Desk 2. However, when the navigation task in VE or GS was taking place, only the participant doing it, was allowed to be in the room.

A 13-in. Asus laptop (Intel®HD Graphics 1792MB) was connected to a 75-in. Samsung 3D TV that was used together with 3D active glasses to display the output from the Unity application for VE navigation and was used as a flat screen display for GS navigation. A wireless keyboard and a mouse were used to navigate in both VE and GS.

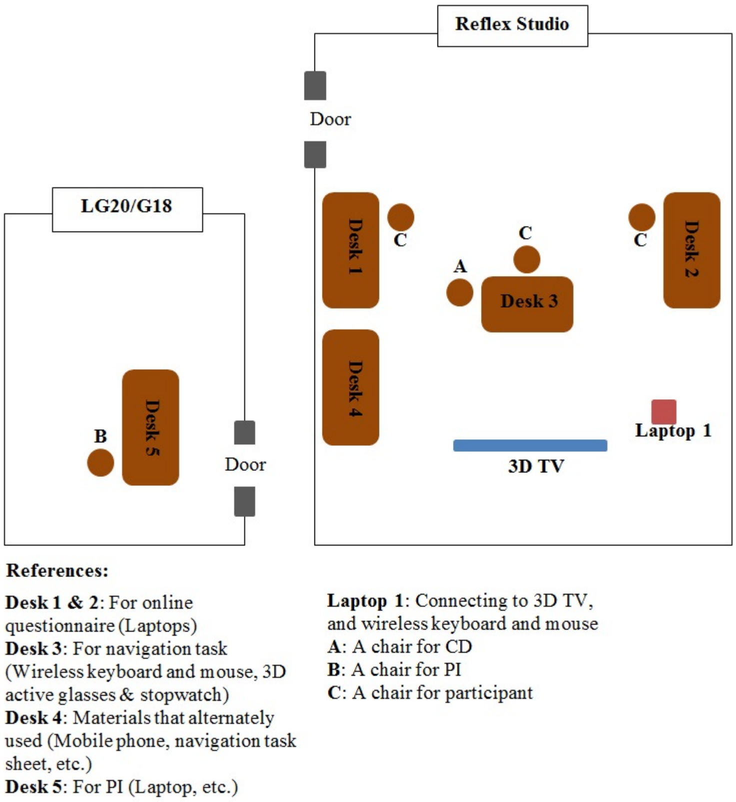


Figure 4.11: Layout of the experimental room

Microsoft Expression Encoder 4 Screen Capture was installed in the same laptop and was used to record the navigation video of VE and GS (Table 4.5).

A stopwatch in the Crane Watch was used to record the navigation time in both VE and GS.

Two sheets of paper contained the navigation instructions (one sheet for VE and another sheet for GS) were provided to the participants who used TP to navigate. Likewise, the instructors for PI and DC modality were given two sets of navigation instructions (one set for VE and another set for GS). A Samsung mobile phone was given to the participants to converse with the instructor, whereas the instructor used a loudspeaker on his Samsung mobile phone in another room that had good coverage for phone use (LG20 or G18, Kroto Research Institute). The Sound Recorder application in Asus laptop was used by the PI to record the conversation. The same Samsung mobile phone running Smart Voice Recorder application was used by the DC to record a conversation with the participants.

The same Samsung mobile phone running RunKeeper application and Global Positioning System (GPS) was used to record the participants' navigation route and time in the RW. An experimenter held it at the back of participants.

4.4 Procedure

Table 4.5 also shows the procedure of experiment with time allocation. The overall time for participants to complete the whole experiment was 75 minutes.

In the experiment formalities, participants were asked to fill in their details, presented with an information sheet and experimental procedure, and asked to sign a consent form. They were given the opportunity to ask any question they might have. They were also clear that they could withdraw at any time without giving any reason and without any negative consequences. They then answered the questions as described in Section 4.3.3.1. For pre-route recognition before the first navigation task, if they drew the route precisely, they then were immediately assigned to the second navigation task. If they did not draw the route correctly or they did not know at all, they simply proceeded to the first navigation task.

Following, they learned to familiarise themselves with a route and travel to a destination in the environment guided by the assigned instructions. The navigation task required them to move from the starting point looking for the destination. In VE and GS navigation task, participants were given 10 minutes to complete it, which was more than twice the duration of the walking time needed to complete it. After 10 minutes, they were asked to stop the task, regardless of whether or not the task has been completed.

After the navigation task, they answered the questions as discussed in Section 4.3.3.3. Then, those who completed the previous navigation (VE or GS) were asked to perform the similar navigation in the RW. The task was carried out by walking. Also, it was done without any instructions or help, although they were accompanied by an experimenter, to test their memory. An experimenter only showed the starting point and recorded the route behind the participants until they finished the navigation. Participants were also given 10 minutes to complete the RW navigation. However, 15 minutes were allocated, including the time needed to walk to the start point and come back to the experimental room.

They then repeated the same procedure for the second navigation task, from the questions on mood in Section 4.3.3.1 to navigation in the RW, if applicable. In the end, they were asked to compare the navigation between VE and GS and provide any comment about the experiment. They were given a bottle of mineral water as soon as they completed the first RW navigation task and once they finished the whole experiment, they were awarded a five-pound reward.

Three different instruction modalities were used in each environment; however, each modality presented the same instructions showing the directions of the similar route. Participants, who used TP to navigate, read the instructions written on a sheet of paper (see Appendix A for detailed instructions). They relied on it until they finished their navigation, without any help. Participants who were instructed by a phone instructor started their navigation as soon as they start communicating. They had to update their current location and orientation to get the next instruction. Participants, who navigated with companion beside, talked to each other face-to-face. Participants who were directed by the instructors (PI or DC) were also allowed to ask questions related to the instructions. The instructions used by the instructors were approximately same as used by the participants who used TP for their navigation (see Appendix A for detailed instructions).

4.5 Results

This section discusses results from the experiment such as information before the learning task, differences amongst six combinations (VE&TP, VE&PI, VE&DC, GS&TP, GS&PI and GS&DC), comparison of navigation environments between VE and GS and finally, comparison of instruction modalities amongst TP, PI and DC.

Before the statistical analysis was done, all data was assessed to determine the normality. If the data was normally distributed, the parametric test, in particular, t-test *(t)* was used, while the nonparametric tests were used if the data was not normally distributed, for example, Kruskal-Wallis *(H)*, Wilcoxon *(W)*, and Mann-Whitney test *(U)*. The SPSS Statistics package version 22 was used to analyse the numerical results in addition to the qualitative analysis of the results.

4.5.1 Pre-Learning Information

The following results explain some information before the main task, for example, spatial and navigational abilities, immersive tendency, overall mood before the first navigation task and pre-route recognition task.

4.5.1.1 Spatial and navigational abilities

A spatial and navigational abilities test was administered. The overall average score on all the questions test was 3.49/5, demonstrating that most participants felt they had an average or above average abilities. In the sample, 8 participants (22.22%) felt they were overall very good, 21 (58.33%) reported having good abilities, and the remaining 7 (19.44%) felt they were poor.

The total score of spatial and navigational abilities between male and female participants was compared. The test showed that there was a significant difference (t (34) = -3.068, p = .004*) (Table 4.6), in which men had significantly better abilities than women.

The results were also confirmed by the female participants' comments after the navigation tasks. Some female participants reported they felt it was difficult to remember routes and landmarks. Also, some women got confused on which was the right road to arrive at the destination in the RW navigation. They moreover mentioned that they neither prefer to navigate in 2D photographic image environment like GS nor perform map-related tasks such as drawing a route on the map.

Table 4.6: Total score of spatial and navigational abilities between genders

	Average	
	Male	**Female**
Total score of spatial and navigational abilities	3.77	3.21

**p <.01; Score ranges from 1 - 5, in which 1 = very poor and 5 = very good*

4.5.1.2 Immersive tendency

Participants also took an immersive tendency test before the learning task. The overall average score was 3.38/5, suggesting that the majority of the participants felt they had an average or above average ability. Of the 36, 2 participants (5.56%) reported that they were overall very good, the majority of the participants (30 - 83.33%) felt that they had a good tendency and the remaining 4 (11.11%) stated having a poor tendency.

The difference between male and female participants was also compared, however, no significant difference was found in the total score (t (34) = -0.326, p = .747), even in each item asked in the test.

4.5.1.3 Overall mood before performing the first navigation task

The overall mood of participants before doing the first navigation task was analysed (Table 4.7). Eight participants (22.22%) were feeling very pleasant before doing the task, 22 (61.11%) felt pleasant, and another 6 (16.67%) felt unpleasant.

Table 4.7: Overall mood before performing the first navigation task

Pre-navigation		***n***	**%**
Overall Mood	Very pleasant	8	22.22
	Pleasant	22	61.11
	Unpleasant	6	16.67

4.5.1.4 Pre-route recognition

Of the 36 participants, 1 woman (2.8%) age around 18 - 24 years old stated that she knew very well how to get to Universal Computers, the destination in the VE. However, the route she drew was not precise as she marked the destination at the wrong place (Figure 4.12). Therefore, she was still included in the study as it was considered that she did not know how to get to the destination. The rest of 35 participants (97.2%) did not know the location of Universal Computers at all (Table 4.8). Similarly, before performing the GS navigation task, all 36 participants (100%) did not know the location of Flame Hardeners Limited, the destination in the GS.

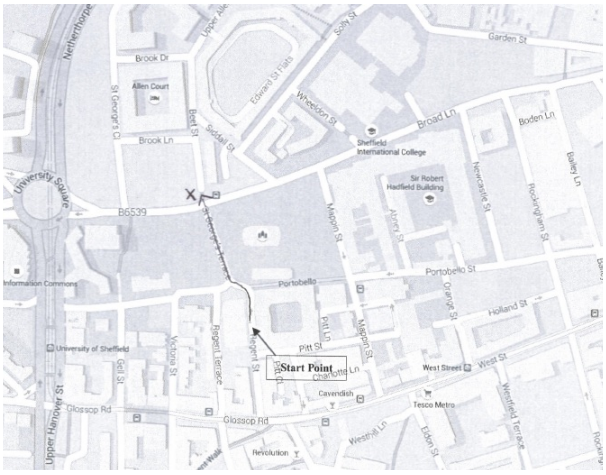


Figure 4.12: VE route imprecisely drawn by a participant

Table 4.8: Pre-route recognition task before navigation

How well do you know the location of		*n*	%
Universal Computers (Location in the VE)	I know very well how to get there	1	2.8
	I know how to get there	0	0
	Not at all	35	97.2
Flame Hardeners Limited (Location in the GS)	I know very well how to get there	0	0
	I know how to get there	0	0
	Not at all	36	100

4.5.2 Differences amongst Six Combinations

This section clarifies the differences amongst all six combinations. Some results show significant differences, such as navigation time in the VE and GS, and users' score, for example, interesting navigation, easy to find the sign of street and easy to navigate by using assigned instruction modality.

4.5.2.1 Navigation time in the virtual environment and Google Street View only

This section discusses the navigation time measuring how long, on average, participants took to finish the navigation in the simulated environments. The difference amongst all six combinations was significant (H (5) = 14.816, p = .011*) (Table 4.9). The combination between VE and PI took the least time, and the combination between GS and TP took the most time. The following relationship presents the difference amongst all six combinations:

VE&PI <VE&DC <GS&DC <VE&TP <GS&PI <GS&TP

Table 4.9: Difference of navigation time

	Average	
	VE	**GS**
TP	0:03:48	0:05:31
PI	0:02:46	0:05:16
DC	0:02:58	0:03:25

**p* <.05; VE = Virtual environment, GS = Google Street View, TP = Text on paper, PI = Phone instructor, DC = Direct companion*

4.5.2.2 Interesting navigation

This section describes how interesting the participants found the navigation in the environment. The difference amongst all six combinations was significant (H (5) = 16.365, p = .006*) (Table 4.10). The combination between VE and TP, between VE and PI, and between VE and DC was the most interesting navigation, and the combination between GS and TP was the most boring navigation. The relationship of difference amongst all six combinations is illustrated as below:

VE&TP, VE&PI, VE&DC >GS&DC >GS&PI >GS&TP

Table 4.10: Difference of interesting navigation

	Average	
	VE	**GS**
TP	4.5	3.33
PI	4.5	3.67
DC	4.5	3.83

**p* <.01; Score ranges from 1 - 5, in which 1 = very boring and 5 = very interesting*

4.5.2.3 Easy to find the sign of street

The score of whether it was easy to find the street sign in the environment was measured. The difference amongst all six combinations was significant (H (5) = 11.536, p = .042*) (Table 4.11). The combination between VE and DC was the easiest to find the sign of street, whereas the combination between GS and TP was the most difficult. The relationship of difference amongst all six combinations is explained as follows:

VE&DC >VE&TP >GS&DC >GS&PI >VE&PI >GS&TP

Table 4.11: Difference of whether it was easy to find the sign of street

	Average	
	VE	GS
TP	3.83	2.75
PI	3.25	3.33
DC	4.25	3.42

**p <.05; Score ranges from 1 - 5, in which 1 = very difficult and 5 = very easy*

4.5.2.4 Easy to navigate by using assigned instruction modality

The participants were asked whether the environment was easy to navigate by using assigned instruction modality. The results show that there was a significant difference amongst all six combinations (H (5) = 23.988, p = .000*) (Table 4.12). The combination between VE and DC was the easiest to navigate, whereas the combination between GS and TP was the most difficult. The relationship of difference amongst all six combinations is described as follows:

VE&DC >VE&TP >GS&DC >GS&PI >VE&PI >GS&TP

Table 4.12: Difference of whether it was easy to navigate with the instruction modality

	Average	
	VE	GS
TP	4.17	2.83
PI	3.25	3.42
DC	4.75	3.58

**p <.001; Score ranges from 1 - 5, in which 1 = very difficult and 5 = very easy*

4.5.2.5 Summary of differences

Other data were also compared such as post-overall mood, presence, post-route recognition, landmarks recall and placement. However, the results indicate that the differences amongst all six groups were not significant. According to all data, the best combination was between VE and DC, and the worst combination was between GS and TP (Table 4.13).

4.5.3 Comparison of Navigation Environments between Virtual Environment and Google Street View

This section describes the navigation comparison between VE and GS, considering various results such as navigation time, navigation experience, navigation video, moods, post-route recognition, landmarks recall and placement, questions asked during navigation and navigation to the VE and GS destination in the RW.

Table 4.13: Summary of differences amongst six combinations

	Best combination	**Worst combination**
Navigation time in the VE and GS only	VE&PI*	GS&TP*
Interesting navigation	VE&TP*, VE&PI*, VE&DC*	GS&TP*
Easy to find the sign of street	VE&DC*	GS&TP*
Easy to navigate by using assigned instruction modality	VE&DC*	GS&TP*
Post-overall mood	VE&PI	GS&TP, GS&PI
Presence	VE&DC	VE&PI
Post-route recognition	VE&TP	GS&TP
Landmarks recall	VE&TP	GS&DC
Landmarks placement	VE&PI	GS&PI

**significant; VE = Virtual environment, GS = Google Street View, TP = Text on paper, PI = Phone instructor, DC = Direct companion*

4.5.3.1 Navigation time

Navigation time was the time taken by participants to finish the navigation in the VE, GS and RW. However, the results from navigation in the VE and GS was used to consider whether participants could perform the same task in the RW (Table 4.14). Of the 36 participants, 35 in the VE and 30 in the GS completed the navigation task, arriving at the destination within the allocated time. They then were asked to perform the similar task in the RW because they were considered to be able to find the destination. In the RW, of these 35 and 30, 34 participants who navigated to the VE destination and 28 participants who navigated to the GS destination, completed the task as same as in the previous VE and GS. From these figures, only 28 participants were considered to complete the navigation task in all four environments (navigation in the VE, navigation in the GS, navigation to the VE destination in the RW and navigation to the GS destination in the RW). Another 8 participants were classed as poor performance due to unfinished task in the VE or GS, or they had taken a different route in the RW, although reaching the destination.

Table 4.14: Success and fail in completing the navigation tasks

	VE	GS	RW-VE	RW-GS	All four environments	At least one environment
All participants	36	36	35	30	–	
Success/good	35	30	34	28	28	–
Fail/poor	1	6	1	2	–	8

The following three sections thoroughly discuss navigation time such as navigation time in the VE and GS only considering all 36 participants, navigation time of good performance that discusses participants who completed in all four environments, and navigation time of poor performance that discusses participants did poorly in at least one of the four environments.

Navigation time in the virtual environment and Google Street View only
It can be seen from the time comparison that navigation in the VE took significantly less time than navigation in the GS (W = 94, p = .000*) (Table 4.15). Regardless of instruction modality, the average time to navigate the given route in VE was 3 minutes and 10 seconds; however, participants took on average of 4 minutes and 44 seconds to navigate in GS.

Table 4.15: Task completion time in the VE and GS

	VE	**GS**
Average time	0:03:10	0:04:44

**p <.001*

In the comment section, mostly participants expressed that VE simulated necessary information only; therefore they got familiar with environment easily which speeded up their navigation. Although the environment was simpler than GS, they agreed that VE was real and engaging, and increased their passion for immersing with the environment and enjoying doing the task. They, also, were free to control the scene movement.

By contrast, GS had much information which was hard to process quickly and sometimes, it was confusing. For example, they found that it was hard to find the signposts and buildings even though they had reached the location as instructed. Secondly, the scene movement was big as it jumped from one point to another point using static pictures. When participants pressed a key to move, either UP or DOWN arrow key, GS showed the scene at a farther point from the previous, making it impossible to see the landmarks in between points. Therefore, they had to keep going backwards and forward looking for landmarks which increased their navigation time. This limitation furthermore dispelled their mood and motivation to enjoy navigating in the GS.

In the VE, 3 of the 36 participants (8.33%), who were 2 men and 1 woman, took less than 2 minutes to complete the task, and 4 participants (11.11%), who were 2 men and 2 women took more than 4 minutes to complete the task. The former in the comment section reported that they were familiar with computers, in particular, 3D game environment. While doing the navigation task, they also aimed to reach the destination as soon as possible. This behaviour is in line with the literature [70] that people try to finish their navigation quickly. However, the latter found that VE was unpleasant such as no avatar to represent the user and the signposts were small, although the signpost was in proportion with the RW scale. They, also, liked navigating in GS more than VE. Of these four, one woman could not complete the navigation task although 10 minutes was given; as such she was considered that would never be able to perform the same task in the RW.

Whereas in GS, 4 out of the 36 participants (11.11%), who were all men, took less than 2 minutes to complete the task. In the comment section, they mentioned that they knew well how to use GS although the route assigned was uncommon for them. However, 9 participants (25%), who were 3 men and 6 women took more than 6 minutes to complete the task. They commented that GS had many landmarks to look and check. They also liked to move in the VE more than GS. Of these 9, 5 participants, who were 1 man and 4 women could not complete the navigation task within the time given (10 minutes); they, therefore, were not qualified to do the same task in the RW. One woman of these 4 was the same woman who could not complete the navigation task in the VE. Furthermore, 1 woman, who gave up navigating in GS after 4 minutes and 13 seconds, was considered not to be able to find the GS destination in the RW.

Navigation time of good performance
Only 28 of the 36 participants (77.78%), who were 17 men and 11 women, were classed as having good performance. The difference between navigation time in the RW after performing the navigation task in the VE and GS was compared. The results show that the time difference between navigation in the RW after performing in the VE and GS was significantly different (t (27) = -2.513, p = .018*) (Table 4.16). In particular, there is the following relationship:

$$\text{RW-GS} < \text{VE} < \text{RW-VE} < \text{GS}$$

Navigation to the GS destination in the RW took the least time. It is followed by navigation in the VE and subsequently, navigation to the VE destination in the RW. However, navigation in the GS took the most time.

Table 4.16: Time difference between RW after performing in the VE and GS

	Average time	**Difference average time between**
VE	0:02:52	0:00:47
RW-VE	0:03:20	
GS	0:03:54	0:01:31
RW-GS	0:02:51	

**p <.05*

The average time to navigate the given route in the VE regardless of instruction modality was 2 minutes and 52 seconds. In the RW, the participants took on average 3 minutes and 20 seconds to complete the navigation they had experienced in the VE. While in the GS, the average time to navigate the given route regardless of instruction manner was 3 minutes and 54 seconds. In the RW, the participants took on a lower average of 2 minutes and 51 seconds to reach the same destination as in the GS. Although reaching the destination in the RW, the navigation time was included considering traffic lights and crossing roads.

It seemed that after spending more time with GS, participants then were faster to reach the same destination in the RW, with average difference time of 1 minute and 31 seconds. However, overall, the difference between task completion time in the VE and RW was nearly the same, where navigation in the RW participants took on average 47 seconds more than in VE. Given that the route in the VE and GS had the same distance; it appeared that after having found the route in the GS, the participants were more readily able to reach the destination in the RW than after having learned the route in the VE.

Nine of the 28 participants (32.14%), who were 5 men and 4 women, took more time to navigate in the VE but they then took less time when navigating to the same destination in the RW. Another 19 participants (67.86%), who were 12 men and 7 women, took less time in the VE but they took more time to finish the same task in the RW. Whereas in the GS, of these 28, 20 participants (71.43%), who were 11 men and 9 women took more time to reach the destination but they then took less time when navigating to the same destination in the RW. The remaining 8 participants (28.57%), who were 6 men and 2 women, took less time in the GS but they took more time to reach the same destination in the RW.

Navigation time of poor performance
Of the 36, 8 participants (22.22%), who were 1 man and 7 women, were considered as having poor performance (Table 4.17) due to unfinished task in the VE or GS, or they had taken a different route in the RW, although reaching the destination.

Table 4.17: Poor performance in the VE, GS and RW

		Navigation time and reason of poor performance							
No.	**Gen.**	**VE**	**Reason**	**RW-VE**	**Reason**	**GS**	**Reason**	**RW-GS**	**Reason**
1	F	0:10:00	Incomplete	*Not applicable*		0:10:00	Incomplete	*Not applicable*	
2	F	0:03:03	–	0:08:27	Giving up	0:04:33	–	0:06:06	Different route
3	F	0:03:57	–	0:07:54	–	0:04:13	Giving up	*Not applicable*	
4	F	0:05:07	–	0:02:56	–	0:10:00	Incomplete	*Not applicable*	
5	F	0:03:19	–	0:03:13	–	0:10:00	Incomplete	*Not applicable*	
6	M	0:03:30	–	0:03:44	–	0:10:00	Incomplete	*Not applicable*	
7	F	0:02:59	–	0:03:23	–	0:10:00	Incomplete	*Not applicable*	
8	F	0:02:14	–	0:04:06	–	0:02:03	–	0:04:49	Different route

Gen. = Gender, M = Male, F = Female

The following analysis briefly describes the performance of the poor participants according to Table 4.17 (see Appendix B for a full analysis).

Participant 1

One woman aged around 25-34 years old, did not complete the navigation in the VE, nor in the GS, as she was unable to find the destination although 10 minutes was allocated. In the VE, she was in the correct direction after passing the construction area, but when she missed the signpost of Brook Hill/B6539, she then lost the direction and decided to move back to previous streets, so losing time. In the GS, she managed to arrive at the final road, where the destination was located. However, she started losing the correct direction when she missed the destination on her left.

Participant 2

One woman aged around 18-24 years old, navigated well in the VE and GS, however, performed poorly in both RW navigations. For the GS destination in the RW, she successfully reached it, but she took a different route. She started losing the correct direction when she missed turning left onto Boden Ln, instead of heading up on Rockingham St. In her navigation to the VE destination in the RW, she gave up to continue the task after 8 minutes and 27 seconds. She started to lose the direction when she turned right onto Portobello, although she had to turn left onto it slightly.

Participant 3

One woman aged around 25-34 years old, successfully reached the destination in the VE, however, in the GS, she stopped navigating after 4 minutes and 13 seconds as she gave up, showing that her navigation was unsuccessful. The video recording reveals that as she missed Rockingham St on her right, she then was uncertain where to head to; making her gave up the navigation.

Participant 4

One woman aged around 25-34 years old, successfully reached the destination in the VE. However, in the GS, she did not reach the destination although 10 minutes was allocated. As observed in the video, she started losing the direction when she missed Rockingham St, although she kept navigating on Broad Ln/B6539.

Participant 5

One woman aged around 25-34 years old, navigated well in the VE. However, after 10 minutes in the GS, she still could not find the destination. As observed in the navigation video, although she kept moving on Rockingham St, she could not spot the location of Boden Ln, so this was the reason she lost the direction in the GS navigation.

Participant 6

A man who aged around 25-34 years old, navigated well in the VE. However, he could not find the destination in the GS although 10 minutes was allocated. The video recording shows that he missed the destination, Flame Hardeners Limited on his left, where he started losing the correct direction.

Participant 7

One woman aged around 25-34 years old, navigated well in the VE. However, she could not find the destination in the GS. As seen in the video, she missed Rockingham St first, where she spent much time on a different route before coming back to the assigned route. She then missed Boden Ln on her left, where she again started losing the correct direction.

Participant 8
One woman aged around 18-24 years old, navigated quite well in the VE and GS. In fact, she took less than the average time. However, she took more time to arrive at both destinations in the RW. Badly, she took the wrong route to reach the GS destination in the RW. As reported in the RunKeeper data, she started losing the correct direction when she missed turning right onto Rockingham St, instead of heading down toward Bailey St, although she managed to reach the destination at the end.

4.5.3.2 Navigation experience

The navigation experience between VE and GS was compared and it is apparent from the results that navigation in the VE was significantly more interesting than GS (t (35) = 4.233, p = .000*) (Table 4.18). These results were also confirmed by the participants' selection when they were asked to compare both environments at the end of the experiment. Of the 36, 22 participants (61.1%) chose VE as the more interesting environment to perform the navigation task. The comment section reported that they were so excited doing the navigation task in the VE because they fully engaged with the environment.

Table 4.18: Interesting navigation in the VE and GS

	Average	
	VE	**GS**
How interesting was your navigation in the environment?	4.5	3.61

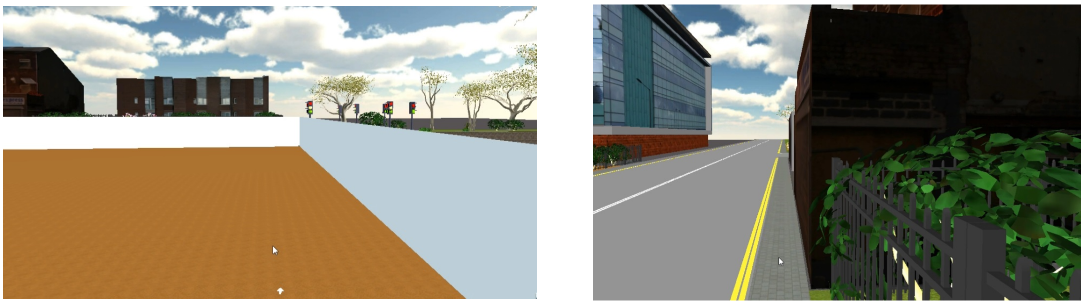
**p <.001; Score ranges from 1 - 5, in which 1 = very boring and 5 = very interesting*

According to choice where they frequently read the street name in the GS, 25 of the 36 participants (69.44%) read it on the street superimposed by GS rather than on the signpost. The street name superimposed by GS consistently appeared on the street every time participants moved onto, or even came close to the street. By contrast, some signposts did not exist at all or were located in the previous picture rather than the current picture where they were. This condition was verified by participants' comments saying that GS did not show clear signposts.

4.5.3.3 Video recording of navigation in the virtual environment and Google Street View

Navigation in the virtual environment
On average the participants spent 3 minutes and 10 seconds to arrive at the destination.

Five of the 36 participants (13.89%) had to put more efforts into finding the final destination in the VE and arrived with a higher than average time. One of them, a woman, never reached the VE destination who was unable to complete the navigation task in this environment at all.



(a) The Diamond construction area (b) Garden

Figure 4.13: Participants navigated on other areas, not on the road

(a) Brook Hill/B6539 signpost (b) Navigated on a garden

Figure 4.14: A woman missed Brook Hill/B6539 signpost

In the video analysis, the behaviour of these 5 participants was observed. Three of them, 1 man and 2 women, did not use the road to reach the destination. Instead, they navigated most of the time inside The Diamond construction area, the garden and even cut through buildings to find their way around, displaying difficulties in using the keyboard keys to navigate in the VE (Figure 4.13). They also tried to find shortcuts to reach the destination instead of following the road with the result that they missed the signposts and got lost. One of these 2 women, who did not complete this task, had unusual behaviour which was not observed in the other participants. She frequently stopped for a long time during navigation, as if she needed more time to read and understand the instructions given on the paper. In the background information, it was shown that her first language was not English. Her navigation video indicates that she missed the Brook Hill/B6539 signpost (Figure 4.14), which made her go back to the previous streets and lost so much time. In the end, she did not complete the task, only 10 minutes were set as a maximum time for the participants to complete the task. However, in the spatial and navigational abilities test, she reported to consider herself as having good abilities.

The behaviour of the remaining 2 male participants (in the group of 5 who took longer than average to reach the destination) was also observed. One man, who took 1 minute

(a) Portobello signpost (b) Turned right onto Portobello

Figure 4.15: A man turned right onto Portobello and kept moving

more than the participants' average time to finish the navigation, turned right onto Portobello and kept on moving, despite the PI kept on encouraging him to go left (Figure 4.15). This behaviour might have been due to his inabilities to distinguish left from right. However, in the spatial and navigational abilities test, this was not confirmed, except that he neither agreed nor disagreed that he was very good at following a sequence of instructions. The other man, while he was navigating on the street close to the destination location (St George's Cl), he passed it and kept moving forward and missed the target. Noticing he had passed it, he turned and got back to the street, finally reaching the target, yet losing time. In the spatial and navigational test, he agreed that he very easily got lost in an unfamiliar area. He also commented that he would have liked for the signposts in the VE to be bigger than the current size. The signposts used in the VE were in proportion to the building, as the same size as in the RW. This comment might indicate that he did not notice the street signpost and missed the target.

In general, navigation in the VE took significantly less time than navigation in the GS, which took on average 4 minutes and 44 seconds. However, 12 out of 36 participants (33.33%) in the VE reported that they found the keyboard navigation for the left and right movement slow. In fact, the video recordings show that when participants changed the scene direction to the right or left (pressing the RIGHT or LEFT arrow key on the keyboard to turn), the scene moved slowly. Apart from that, the results of Presence Questionnaire [237] show that there was a significant difference in one of the seven questions, asking whether the participants lost track of time in the navigation task (t (35) = -2.395, p = .022*). On average the participants reported a higher value in the GS, indicating that they lost track of time during navigation in the GS more easily than in the VE. Of the 36, 20 participants (55.56%) reported having lost much track of time in the GS. However, there was no significant difference in the total score of presence between VE and GS (t (35) = 0.274, p = .786) (Table 4.19).

Navigation in the Google Street View

In the GS navigation, participants took on average 4 minutes and 44 seconds, and the navigation video furthermore showed that 26 of the 36 participants (72.22%) had to put more efforts to complete the navigation task. However, 20 out of these 26 participants (76.92%) managed to arrive at the destination in the given time, while 6 participants

Table 4.19: Presence in the VE and GS

	Average	
	VE	**GS**
Total score of presence	3.33	3.29
Item 1: Were you involved in the experimental task to the extent that you lost track of time?	2.56	3.14

**p <.05; Score ranges from 1 - 5, in which 1 = not at all and 5 = very much*

(23.08%) did not complete the task at all. Of these 6, 1 woman who also did not complete the VE navigation task, reported having good spatial and navigational abilities.

(a) Boden Ln

(b) Rockingham St

Figure 4.16: Streets missed by the GS participants

Nineteen of the 26 participants (73.08%) missed at least one street during their navigation. The most streets they missed were Boden Ln and Rockingham St (Figure 4.16). They missed these streets because they could not see the street name, either on the street itself or the signpost.

Although the nice feature of GS that showed the street's name very clearly and with large letters on the street itself, the name only appeared when the participants came close to the street. Otherwise, the participants needed to rely on the picture of the street, which might be signposted in the RW, to see its name. In this case, it was possible to miss the street name if just passing nearby the street. When both signposts in the RW and name on the street superimposed by GS were present, the road was labelled twice. By contrast, in the VE, every road was signposted once using a standalone signpost which in proportion to the RW size, that was with small letters as compared to the name on the street given by GS, but it was always present.

For Boden Ln, there was no signpost with the street's name in the RW and therefore, neither the GS pictures, unless the name was on the street that was superimposed by GS, which might be the reason why it was missed. For Rockingham St, the signpost was not clearly visible as it was displayed far from the point in which the RW picture stored in the GS was taken (Figure 4.17). Also, when the participants pressed the UP arrow key

(a) The signpost in the first picture

(b) No signpost in the next picture

Figure 4.17: The signpost of Rockingham St

to move forward, GS showed the scene at the farther point from the previous, making it impossible to see the signpost on the left side. These two streets had been missed by 4 participants (2 missed Boden Ln and 2 missed Rockingham St), who did not complete the task at all.

Due to the limitation of scene movement in the GS that jumps from one point to another point using static pictures, 13 of these 26 participants (50%) missed the destination, leaving Flame Hardeners Limited on their left as they moved forward to the next picture shown by GS. Of the 13, 11 managed to go back to the destination, while 2 participants did not see it, having left it behind, and never managed to go back.

Figure 4.18: A participant turned left onto Broad Ln/B6539

One of the 26 participants, a woman, turned left onto Broad Ln/B6539 and kept moving forward (Figure 4.18), although the instruction on the paper asked her differently. In the spatial and navigational abilities test, she neither agreed nor disagreed that she was very good at following a sequence of instructions. She also neither agreed nor disagreed that she very easily got lost in an unfamiliar area.

Two men and 1 woman, of the 26, also, turned left onto Bailey Ln (Figure 4.19), although they should have turned right as requested by instructions (either TP or PI). In

Figure 4.19: Participants turned left onto Bailey Ln

the spatial and navigational abilities test, the woman disagreed that she was very good at following a sequence of instructions. This answer confirmed her action to move differently to the instructions given by instructor although she commented she liked GS more than VE for navigation. The two men agreed that they were very good at following a sequence of instructions, they neither agreed nor disagreed that they very easily got lost in an unfamiliar area. However, their behaviour showed otherwise.

Figure 4.20: A restaurant where a man navigated in

Another man of the 26 who put more effort to complete the task, took 6 minutes and 30 seconds to arrive at the destination, as he had entered a building and navigated through it for approximately 1 minute and 26 seconds looking around inside. The geometry of the building inside showed a restaurant (Figure 4.20). The participant felt that it was hard to control the movement in GS as every time he pressed the key, GS jumped to the distant location. He also commented that environment in the GS was more cluttered than the setting in the VE.

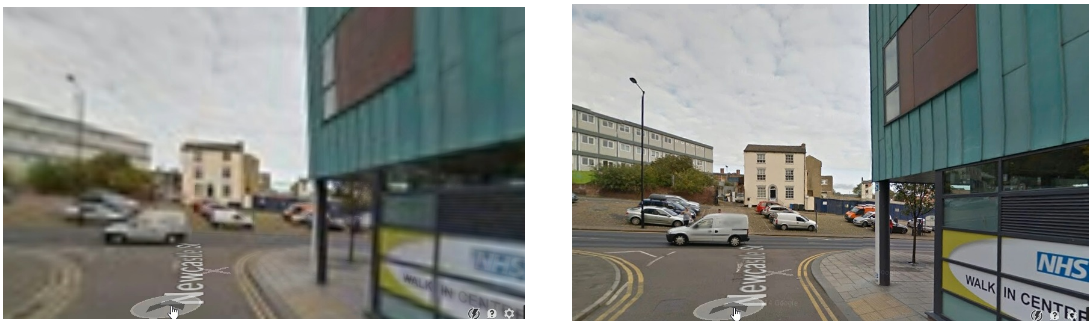
Interestingly, the video recording of this man reveals that GS had combined the scene using both daytime and night time pictures. In fact moving to the right of Rockingham

(a) At night time

(b) During daytime

Figure 4.21: Pictures combination of Rockingham St

St (from Division St), the scene displayed in the picture was taken during night time, and when moving to the left of Rockingham St (from Division St), the scene displayed was taken during daytime (Figure 4.21).



(a) A fuzzy picture

(b) A clearer picture

Figure 4.22: A fuzzy picture in the first place got clearer

The video recording of navigation in GS show in general that GS took some time to display the scene clearly to participants. It started with a fuzzy picture that got clearer as the picture was loaded (Figure 4.22). For example, when pressing the UP arrow key, GS showed the scene at a further point in front a little blurry. After 1 second, the scene became clearly visible. By contrast, the VE always had all the elements in the world clearly visible, never blurred.

GS at times had human or cars in the environment, captured as they moved along the street. However, in one picture the people or cars were at one point, and they moved to the different point by the time the second picture was taken by GS. As such, the people or cars could not be used as reference point for navigation.

GS at the bottom left of the screen displayed a small 2D map with the little character that was concurrent to the movement of the participants in the environment, indicating the participants' position on the map (Figure 4.23). This navigation aid might have helped the participants to look for the right street to take, although some participants might not have noticed or used it.

Figure 4.23: Small 2D map with the little character in the GS

Similarity in the participants' behaviour in both virtual environment and Google Street View
The navigation videos of both environments show that 3 participants in the VE and 14 participants in the GS displayed a car driving like behaviour using the DOWN arrow key as in the reverse mode on cars when they realised to be navigating in the wrong direction. This behaviour allowed staying in the same position while pictures were loaded from the back to the front of the scene. In brief, they moved back without turning.

By contrast, 10 participants in the GS, when they noticed they were following a wrong path, they first turned 180 degrees (using the LEFT or RIGHT arrow key on the keyboard repeatedly) to face the street backwards, as human do while walking. The spatial and navigational abilities of the 17 and 10 participants were accessed. The latter reported having better "sense of direction" than the former although there was no significant difference between these two groups ($U = 49$, $p = .198$).

4.5.3.4 Moods

Mood differences between pre- and post-navigation for both VE and GS were compared. The results of pre- and post-overall mood show after navigation, VE significantly improved participants' mood ($W = 19.5$, $p = .025$*) (Table 4.20). Eleven of the 36 participants (30.56%) reported that they felt more pleasant after doing the navigation task in the VE. By contrast, GS appeared to decrease their mood after navigation, although there was no significant difference between pre- and post-overall mood ($W = 12$, $p = .366$).

Navigation in the VE significantly increased participants' happiness ($W = 6$, $p = .005$*) (Table 4.21). Of the 36, 11 participants (30.56%) felt happier after navigating in the VE. The comment section reported that they enjoyed navigating in the VE because it was real and easy to navigate. Besides, they liked it. Conversely, although there was no significant difference between pre- and post-happy mood ($W = 10.5$, $p = .142$), after navigation, GS seemed to reduce their happiness.

Table 4.20: Pre- and post-overall mood in the VE and GS

	Average	
Overall Mood	**Pre**	**Post**
VE	3.08	3.36
GS	3.14	3.03

**p <.05; Score ranges from 1 - 4, in which 1 = very unpleasant and 4 = very pleasant*

Table 4.21: Pre- and post-happy mood in the VE and GS

	Average	
Mood: Happy	**Pre**	**Post**
VE	3.17	3.47
GS	3.31	3.11

**p <.01; Score ranges from 1 - 4, in which 1 = definitely do not feel and 4 = definitely feel*

4.5.3.5 Post-route recognition

The total averages of post-route recognition and navigation time in the VE and GS are reported in Table 4.22. The results show that all participants performed well in this task, both for VE and GS.

Table 4.22: Averages of post-route recognition and navigation time

	Total average
Post-route recognition combining VE and GS	13.92
Post-route recognition for VE only	7.14
Post-route recognition for GS only	6.78
Navigation time in the VE	0:03:10
Navigation time in the GS	0:04:44

Post-route recognition score: Higher value indicates more precise with the maximum score of 9 for each environment

Out of the 36 participants, 22 (61.11%) recognised the route more precise than the average score combining VE and GS; 12 of these 22 participants (54.55%) took less time than average to finish both navigations, indicating that they were aware of the routes although spending less time during navigation.

When considering the participants according to gender groups and the sum of both VE and GS together, Table 4.23 reveals that men significantly recognised the routes better than women ($U = 68.5$, $p = .003$*).

Furthermore, in the comment section, female participants claimed that they could not

Table 4.23: Average of post-route recognition score between men and women

	Average	
	Males	**Females**
Total score of post-route recognition (combining VE and GS)	15.89	11.94

**p <.01; Higher value indicates more precise with the maximum score of 18*

recall the route well and sometimes they were confused by the correct streets. They moreover said the route recognition task (drawing a route on the map) was a challenging task.

4.5.3.6 Landmarks recall

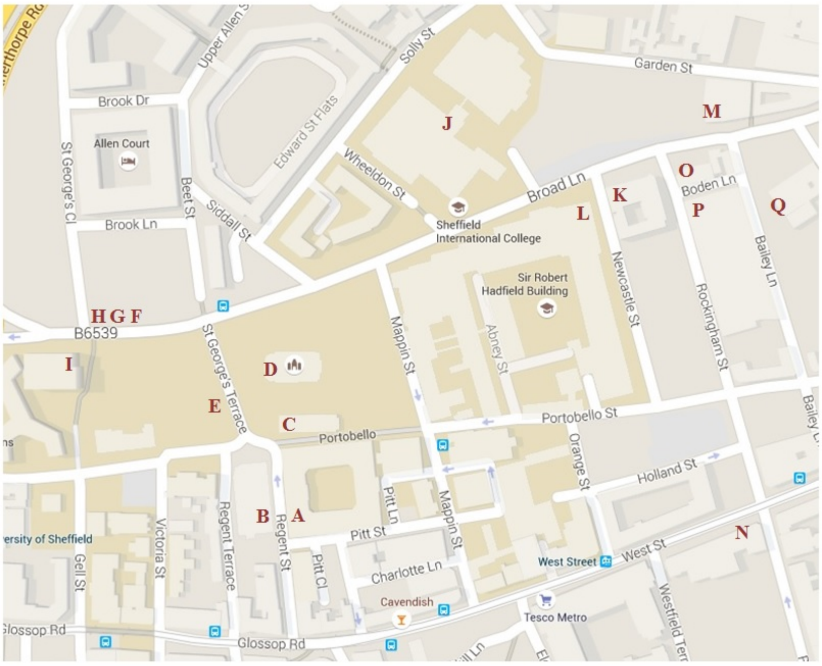
The results of landmarks recall shows that for VE, all participants performed well, but for GS, one woman aged around 25-34 years old, surprisingly did not recall any landmark at all from her navigation in the GS. Apart from that, the comparison results of landmarks recall between VE and GS indicate that navigation in the VE significantly recalled more landmarks than navigation in the GS ($W = 55$, $p = .01^*$) (Table 4.24). Of the 36, 17 participants (47.22%) recalled more landmarks in the VE than GS. The comment section reported that participants agreed that GS provided many landmarks. However, it was difficult to recall the landmarks they had seen during navigation. In contrast, the simpler situation in the VE encouraged them to remember more landmarks.

Table 4.24: Landmarks recalled in the VE and GS

	Average	
	VE	**GS**
Total of landmarks recalled	3.11	2.36

**p <.05; Higher value indicates more landmarks were recalled*

Figure 4.24 illustrates the location of every building recalled from navigation in the VE and GS. In the VE, nine buildings were recalled such as Regent Court, Innovation Centre, University of Sheffield Enterprise (USE), church (St George's Lecture Theatre), The Diamond (considered as building although it was under construction), Butlers Express (shop), Tasteez (food shop), Yep Yep Hot Pot (food shop) and Bioincubator. Whereas in the GS, eight buildings were recalled such as Kroto Research Institute, NHS Walk-in Centre, Pam Liversidge, shop at Broad Ln/B6539, shop at West St, Window Centre (shop), Silver Steel House (owned by Grunwerg Ltd) and warehouse (it was close to the destination). The total of buildings between the environments was measured. The test indicated that navigation in the VE significantly recalled more buildings than navigation in the GS (t (35) = 2.360, $p = .024^*$), in which 19 of the 36 participants (52.78%) recalled more buildings in the VE than GS (Table 4.25). According to the results, church (St George's Lecture Theatre) in the VE and NHS Walk-in Centre in the GS were the landmarks the participants remembered most.



References:

A: Regent Court; B: Innovation Centre; C: University of Sheffield Enterprise (USE); D: Church (St George's Lecture Theatre); E: The Diamond (construction area); F: Butlers Express (Shop); G: Tasteez (Food shop); H: Yep Yep Hot Pot (Food shop): I: Bioincubator

J: Kroto Research Institute; K: NHS Walk-in Centre; L: Pam Liversidge; M: Shop at Broad Ln/B6539; N: Shop at West St; O: Window Centre (Shop); P: Silver Steel House; Q: Warehouse

Figure 4.24: Location of building recalled from the VE and GS

Table 4.25: Buildings recalled in the VE and GS

	Average	
	VE	**GS**
Total of buildings recalled	2.11	1.47

**p <.05; Higher value indicates more buildings were recalled*

The number and the location of each landmark in both VE and GS were examined. The results show that participants seemed to remember more landmarks located in the middle of navigation (not from the beginning).

4.5.3.7 Landmarks placement

Table 4.26 shows the averages of landmarks placement combining VE and GS, and for each environment. Of the 36, 11 participants (30.56%) placed all landmarks they had recalled from VE and GS correctly than the average score combining VE and GS. However, 4 of the 36 participants (11.11%) could not place the landmarks they had recalled from both VE and GS at all.

Table 4.27 shows the averages of landmarks recall, post-route recognition and naviga-

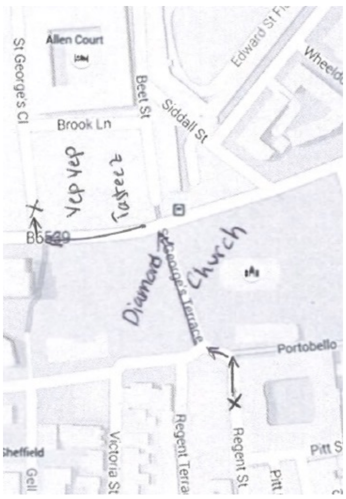
Table 4.26: Averages of landmarks placement score

Landmarks placement score	Total average
Combining VE and GS	1.32
For VE only	0.71
For GS only	0.61

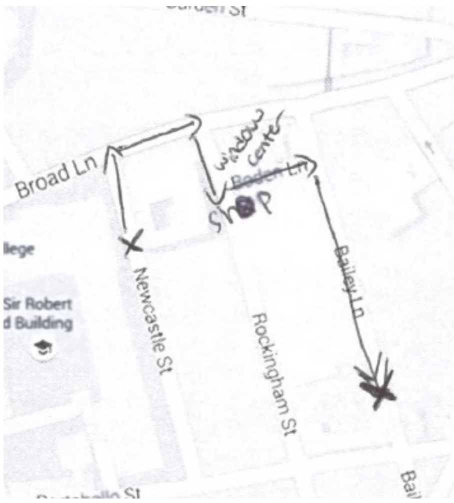
tion time in both VE and GS. When comparing the landmarks placement score with other averages in Table 4.27, 2 of the 11 participants (18.18%), who were 1 man and 1 woman recalled more landmarks than average (both obtained a score of 6), recognised route more precise than average (both obtained a score of 17.5) (Figure 4.25 and 4.26) and even took less time than average to finish navigation in both VE (2 minutes and 16 seconds, and 1 minute and 57 seconds respectively) and GS (1 minute and 56 seconds, and 2 minutes and 2 seconds respectively). As reported in the spatial and navigational abilities test, they considered themselves as having good abilities.

Table 4.27: Related averages

	Total average
Total of landmarks recalled combining VE and GS	5.47
Total score of post-route recognition combining VE and GS	13.92
Navigation time in VE	0:03:10
Navigation time in GS	0:04:44

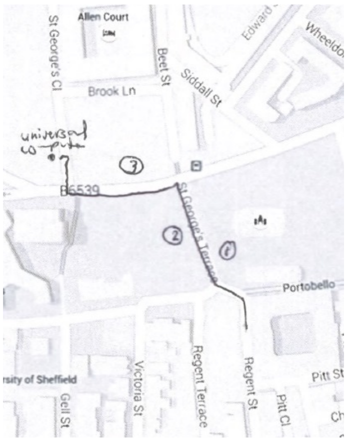


(a) VE map

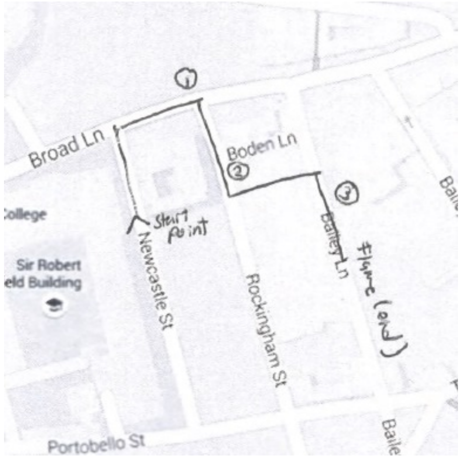


(b) GS map

Figure 4.25: Landmarks placement and post-route recognition by a man



(a) VE map



(b) GS map

Figure 4.26: Landmarks placement and post-route recognition by a woman

4.5.3.8 Questions asked during navigation

Twenty-four participants were assigned to PI (12 in the VE and another 12 in the GS). From the analysis, four types of question were identified such as 1) asking the next instruction after they had done the previous one, 2) asking for confirmation on instructions, 3) asking more information related to instructions given, and finally, 4) asking for help on navigation.

The conversation with PI indicate that navigation in the VE significantly triggered the participants to ask fewer questions than navigation in the GS (t (22) = -4.323, p = .000*), suggesting that the participants managed to get familiar with VE quickly that helped them to move faster (Table 4.28). Of the 12 who navigated in the VE, 5 participants (41.67%) asked fewer than four questions during navigation, whereas in the GS, only 1 participant of the 12 (8.33%) asked fewer than four. These results moreover were confirmed by them, commenting that VE was simple and easy to use.

Table 4.28: Questions asked to PI

	Average	
	VE	**GS**
Total of questions asked by participants	3.50	8

**p <.001; Higher value indicates more questions were asked*

Furthermore, participants in the VE significantly asked fewer questions on information related to instructions than participants in the GS (U = 13.5, p = .001*) (Table 4.29). Interestingly, 6 of the 12 participants (50%) in the VE did not ever ask this type of question along with their navigation. These results prove that VE provided enough and clear information for navigation. By contrast, participants commented that it was hard to locate the landmarks they were looking for in the GS, although GS had the whole environment with all landmarks that were similar to the RW. This difficulty, therefore, required them to ask more information from the instructor to arrive at the destination.

Table 4.29: Questions on information related to instructions

	Average	
	VE	GS
Total of questions on information related to instructions	0.58	2.83

**p <.01; Higher value indicates more questions were asked*

4.5.3.9 Navigation in the real world

The data from RunKeeper was used to observe the behaviour of participants during navigation in the RW. The results of participants, who had unusual behaviour which was not observed in other participants, were then compared to the results of one of the post-route recognition scoring elements (drawing all five streets of the route). Also, the behaviour of participants who did not completely draw the streets on the map was also observed in the data from RunKeeper. The following results describe navigation in the RW when navigating to the VE and GS destination.

Navigation to the virtual environment destination
Of the 36 participants who navigated in the VE, almost all 35 (97.22%) could perform the similar task in the RW afterwards. Another 1 participant (2.78%) who was a woman did not navigate in the RW as she did not complete the navigation task in the VE, although 10 minutes were allocated.

According to the results of post-route recognition, only 27 participants of the 36 (75%) completed all five streets involved in the VE navigation, and another 8 (22.22%) did not complete including the woman who did not complete the task in the VE. The remaining 1 participant (2.78%) surprisingly did not draw at all.

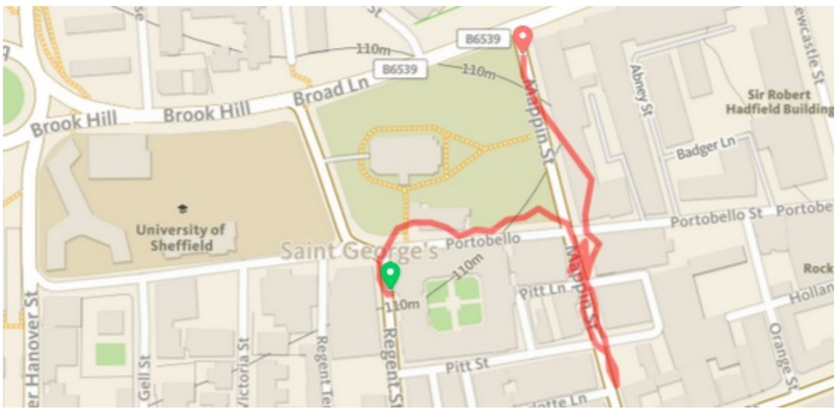
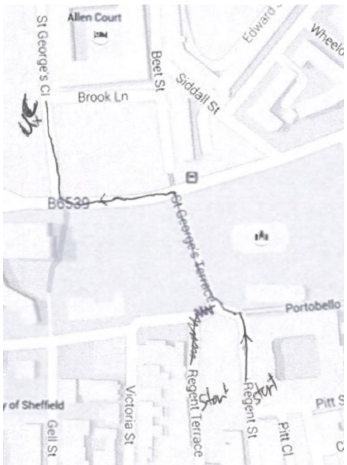
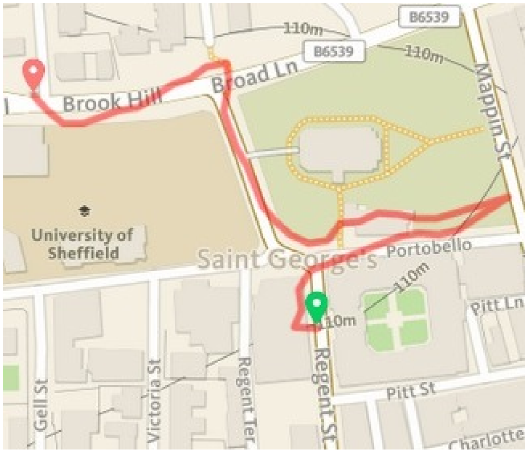


Figure 4.27: RunKeeper route shows a woman gave up

As shown in the route from RunKeeper (Figure 4.27), 1 woman out of the 35 (2.86%) did not complete the navigation in the RW as she suddenly gave up in the middle, although she had spent more than 8 minutes looking for the VE destination. Another 34 participants (97.14%) reached the VE destination in the RW by using the same route as in the VE before.



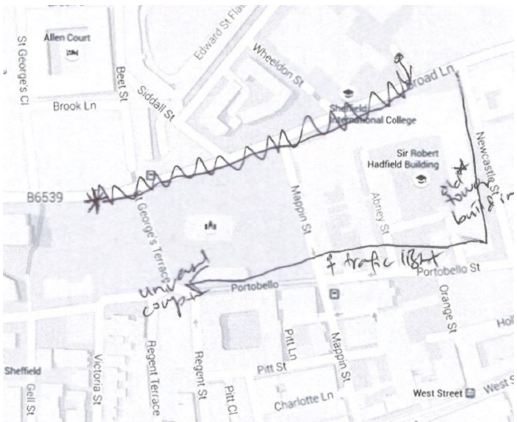
(a) Post-route recognition



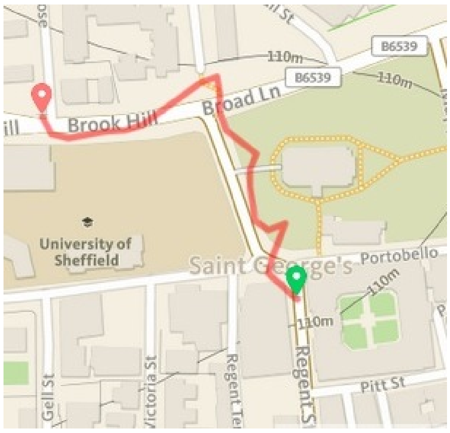
(b) RunKeeper route

Figure 4.28: Correct streets in the drawings but different street in the RW

According to the comparison analysis, of the 35, 9 participants (25.71%) who were 1 man and 8 women showed an interesting behaviour. One woman of the 9 participants (11.11%) completed the precise route following her navigation in the VE (Figure 4.28a). However, in the RW, she took the different street at the beginning of her navigation (Figure 4.28b). Noticing she had taken a different street, she turned and got back to the actual street, finally reaching the destination.



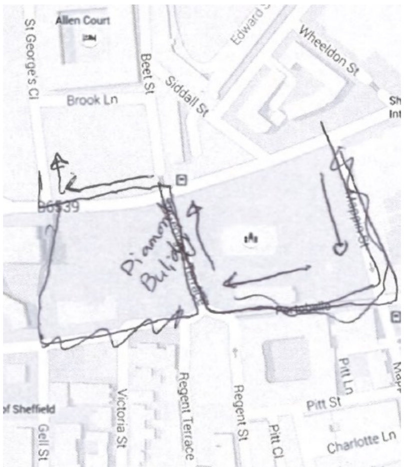
(a) Post-route recognition



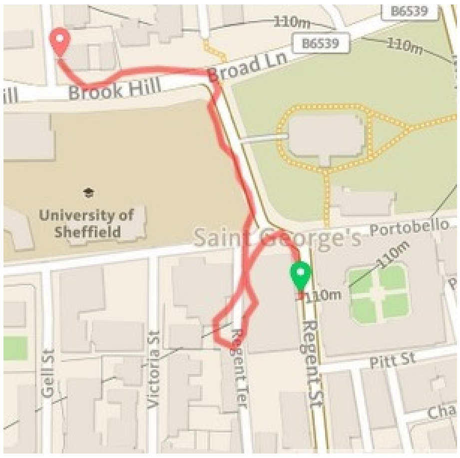
(b) RunKeeper route

Figure 4.29: No correct street in drawing but complete route in the RW

Another 5 participants of the 9 (55.56%), who were 1 man and 4 women did not complete the route on the map, displaying that they could not recall all the streets from their navigation in the VE. However, they successfully finished the navigation in the RW by using the same route assigned in the VE previously. Interestingly, 1 woman from the group of 9 (11.11%) did not draw even a correct street on the map following her navigation in the VE (Figure 4.29a), however, she managed to finish the navigation in the RW by using the similar route as instructed in the VE (Figure 4.29b).



(a) Post-route recognition



(b) RunKeeper route

Figure 4.30: Incomplete route in drawing and different street in the RW

Of the 9, 1 participant (11.11%) who was a woman drew the incomplete route (Figure 4.30a). As showed in her data from RunKeeper, she took the different street at the beginning of her navigation in the RW (Figure 4.30b). However, she turned and got back to the actual street, finally reaching the destination.

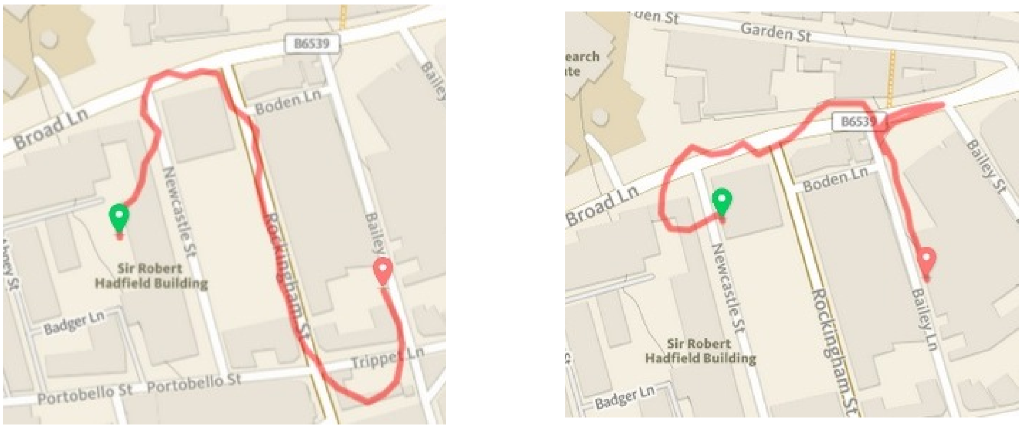
Figure 4.31: Incomplete route drawn by a woman who gave up in the RW

The remaining 1 woman (11.11%) who suddenly gave up in the RW navigation (Figure 4.27) drew the incomplete route on the map (Figure 4.31). Due to her incomplete drawing, this confirmed her action to give up in the middle of navigation as she might not know the correct directions to reach the same destination in the RW.

Navigation to the Google Street View destination

Only 30 of the 36 participants (83.33%) were allowed to navigate to the GS destination in the RW. Another 5 participants (13.89%) who were 1 man and 4 women did not perform in the RW as they did not complete the navigation in the GS, although 10 minutes were given. The remaining 1 (2.78%) who was a woman, did not navigate in the RW because she suddenly gave up the GS navigation. Therefore she was considered not having completing the task in the GS.

As reported in the results of post-route recognition, only 22 of the 36 participants (61.11%) completed all five streets involved in the GS navigation. Whereas another 14 participants (38.89%) did not complete the route on the map, including the 6 participants, who did not complete the navigation task in the GS.



(a) Woman 1 (b) Woman 2

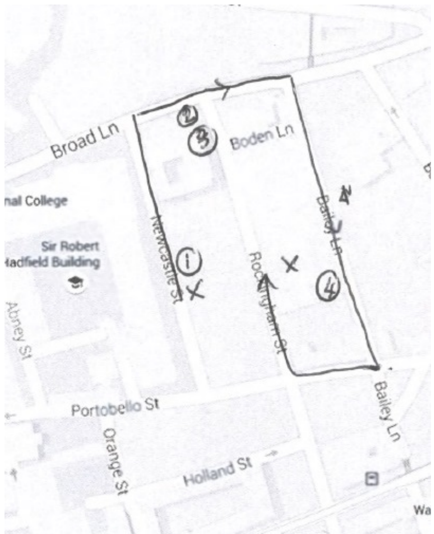
Figure 4.32: RunKeeper routes show that two women took a different route

The data of RunKeeper show that, of the 30 participants in the RW navigation, only 28 (93.33%) reached the GS destination by using the same route as in the previous GS navigation. The remaining 2 participants (6.67%) who were women, however, took a different street, although reaching the destination (Figure 4.32). One of these women was the same participant who suddenly gave up in navigating to the VE destination in the RW.

According to the comparison analysis, 8 of the 30 participants (26.67%) who were 1 man and 7 women displayed an interesting behaviour. Of the 8 participants, 6 (75%) who were 1 man and 5 women drew the incomplete route on the map, indicating that they could not recall all five streets from navigation in the GS. However, they managed to finish the navigation in the RW by using the same route assigned in the GS before.

Of the 8 participants, the 2 women (25%) who took the different street in their navigation in the RW (Figure 4.32) drew the incomplete route on the map (Figure 4.33).

(a) Woman 1



(b) Woman 2

Figure 4.33: Incomplete routes by women who took a different street in the RW

The incomplete drawing proved their behaviour that taking the different route in the RW, showing that they might not be sure the correct route to complete the navigation, although finally reaching the destination.

Participants' behaviour in the virtual environment and Google Street View
The data from RunKeeper show that 2 women performed poorly in the RW navigations. One of them was the woman who gave up when navigating to the VE destination and also took different street when looking for the GS destination, and another woman who took different street when navigating to the GS destination. They, in the comment section, reported that their performance was poor as they could not recall the correct route when navigating in the RW, in particular, navigation to the GS destination.

As reported in the results of RunKeeper and post-route recognition, in both RW navigations (to the VE and GS destination), several participants managed to find the destination using the same route as instructed in the previous VE or GS, although they did not complete the route on the map immediately after their VE or GS navigation. These results indicate that they might be unable to recall correctly in a 2D environment (e.g. on a map or blank paper), however when they were completely in a 3D environment such as in the RW itself, they were likely to engage with surroundings, therefore allowed them to remember the route more precise.

4.5.4 Comparison of Instruction Modalities amongst Text On Paper, Phone Instructor and Direct Companion

The data from both VE and GS was combined to see whether there were significant differences across three instruction modalities. Considering both VE and GS, 24 participants were assigned to each instruction modality, in which 12 participants were from each environment.

4.5.4.1 Differences amongst the three instruction modalities

Easy to navigate by using assigned instruction modality
DC was significantly easier to use when navigating than TP and PI (H (2) = 7.649, p = .022*) (Table 4.30). When comparing between two types of instruction modalities only, DC was also significantly easier than TP (H (1) = 4.185, p = .041*) and PI (H (1) = 7.267, p = .007*) (Table 4.31). However, there was no significant difference between TP and PI (H (1) = 0.139, p = .709). Of 24 who were instructed by the DC, 11 participants (45.83%) scored '5', indicating that the instructions directed by the DC were very easy to use when navigating in the environment.

Table 4.30: Easy to navigate amongst instruction modalities

	Average		
	TP	**PI**	**DC**
Easy to navigate by using assigned instruction modality	3.5	3.3	4.17

**p <.05; Score ranges from 1 - 5, in which 1 = very difficult and 5 = very easy*

Table 4.31: Easy to navigate when comparing two modalities only

Easy to navigate between	***H (1)***	***p***
TP, PI	0.139	.709
TP, DC	4.185	.041*
PI, DC	7.267	.007*

**p <.05 or *p <.01*

Navigation time in the virtual environment and Google Street View
Although there was no significant difference amongst the three instruction modalities (H (2) = 3.468, p = .177), participants took less time to finish the navigation when were directed by the DC beside them (Table 4.32). The comparison between two modalities was also observed and interestingly, navigation that was instructed by the DC significantly took less time than navigation by using TP (H (1) = 3.922, p = .048*) (Table 4.33). In particular, when the participants used DC, it took them on average 3 minutes and 11 seconds, while with TP; it took them 4 minutes and 39 seconds on average to reach the destination. Of 24 who were instructed by the DC, 13 participants (54.17%) took less than 3 minutes to finish the navigation, whereas when using TP, only 7 participants (29.17%) took less than 3 minutes. However, the results of another two pairs do not show significant differences, that are comparison between TP and PI (H (1) = 0.436, p = .509), and PI and DC (H (1) = 0.861, p = .353).

Summary of differences
Another data were also compared such as interesting navigation, easy to find the sign

Table 4.32: Navigation time amongst instruction modalities

	Average		
	TP	**PI**	**DC**
Navigation time	0:04:39	0:04:01	0:03:11

Table 4.33: Navigation time when comparing two modalities only

Navigation time between	***H (1)***	***p***
TP, PI	0.436	.509
TP, DC	3.922	.048*
PI, DC	0.861	.353

$*p < .05$

of street, post-overall mood, presence, post-route recognition, landmarks recall and placement, however, the results indicate that the differences across three instruction modalities were not significant. According to all data, seven results (77.78%) show that DC had better averages, followed by PI (Table 4.34).

Table 4.34: Summary of differences amongst instruction modalities

	Better average	**Significance**
Easy to navigate by using assigned instruction modality	DC	Significant
Navigation time in the VE and GS	DC	Significant only between TP and DC
Post-overall mood	DC	No
Interesting navigation	DC	No
Easy to find the sign of street	DC	No
Presence	DC	No
Post-route recognition	PI	No
Landmarks recall	TP and PI	No
Landmarks placement	DC	No

4.5.4.2 Conversation recording with the phone instructor and direct companion

Questions asked during navigation

Navigation that was instructed by the DC significantly triggered participants to ask fewer questions than navigation instructed by the PI (t (46) = -2.826, p = .007*), suggesting that participants felt it was easier to navigate when instructed by the DC (Table 4.35). Of the 24 participants who were instructed by the DC, 9 (37.5%) asked fewer than three questions during navigation, whereas when instructed by the PI, only 4 participants of the 24 (16.67%) asked fewer than three. These results moreover were confirmed by them, commenting that it was easier to find the destination when instructed by a DC as it gave immediate instructions and correction.

Table 4.35: Questions asked to the PI and DC

	Average	
	PI	DC
Total of questions asked by participants	5.75	3.42

**p* <.01; Higher value indicates more questions were asked*

Participants' performance

Participants who instructed by the PI asked more information about instructions nearby landmarks and correct directions, to reach the destination (Table 4.36). However, participants who were directed by the DC, they asked how they were supposed to move within the environment, either as a car which they were required to go on the road or as a pedestrian who had to walk on the pavement. Regarding navigation desire, the former showed that they tried to reach the destination as soon as possible. By contrast, the latter were found to be more relaxed during navigation in the environments.

Table 4.36: Differences on participants' performance

	PI	DC
Types of questions asked	Asked more information on landmarks and directions to reach the destination	Asked how they should move, either as a car or a pedestrian
Participants desire	Tried to reach the destination as soon as possible	Felt more relaxed while navigating

The recordings also reveal a few unique behaviours of participants due to direct contact to the DC, allowing easy communication and immediate feedback. During the navigation, some participants showed the following behaviour: 1) participant asked about the movement speed in the VE, 2) participant asked about blurry scenes in the GS, 3) participant requested to use a mouse instead of the keyboard in the GS, and 4) participant simply instructed companion to stop giving instruction to let him finishing the current action.

4.5.4.3 Participants' comments

In the comment section, 10 of the 36 participants (27.78%) reported that DC was a better instruction modality for navigation task because 1) it was a direct conversation, 2) DC corrected them immediately if they were in the wrong direction, 3) it was easy to find the destination they were heading to, and finally 4) DC reduced their pressure when performing the task. In contrast, 3 of the 36 participants (8.33%) found that this modality restricted their performance in a few ways such as 1) participants completely focused on instructions given by the DC, so they did not look around in the environment when navigating, 2) it was hard to recall the streets and landmarks because they did not focus on surroundings when navigating, 3) some of them easily got distracted and felt nervous because the companion was beside them, and 4) they were likely to feel guilty and stressed when making mistakes during navigation.

Of the 36, only 1 participant (2.78%) found PI was good. She claimed that she did not feel guilty to make mistakes while navigating because she did not see the instructor. However, 7 of the 36 participants (19.44%) reported that PI was poor due to the following reasons: 1) the instructions were not clear enough, they then got lost during navigation, 2) they easily got distracted as they had to listen and understand the instructions, and navigate concurrently, 3) they suddenly got confused as their current location and orientation were not aligned with the instructions were being given, and 4) they found that it was difficult to follow the instructions which demotivated them to complete the navigation task.

For TP, 3 participants of the 36 (8.33%) claimed that this modality was better than PI for two reasons: 1) as they read the instructions by themselves, they, therefore, found it was easier to navigate to the destination, and 2) as they had to find the landmarks by themselves, so they had to check their surrounding that helped them to recall the landmarks better. By contrast, of the 36, 5 participants (13.89%) commented that TP was poor because they found it was difficult to locate the destination in given time (10 minutes) which subsequently ruined their mood after the navigation.

4.6 Discussion

The main findings of the experiment are summarised below.

Variables combination
According to users' self-reported score, participants felt that it was easier to navigate and find the street sign in the virtual environment and with the direct companion. They also felt that the navigation was more interesting in the virtual environment, regardless of instruction modalities. However, the task completion time was less in the virtual environment and when with the phone instructor. The worst combination was navigation in Google Street View with instructions (or text) on paper as it took the most time, it was the most boring navigation, it was the most difficult to find the sign of streets and it was the most difficult to navigate.

Learning experience and moods
With regards to visual representations, navigation in the virtual environment took less time than in the Google Street View. These findings are supported by navigation videos, demonstrating that in the Google Street View participants took more effort to complete the task as they experienced difficulties (e.g. looking around and making sense of the scenes participants jumped to, recovering from mistakes and missing signposts). Therefore they took more time. They also felt that they lost track of time when dealing with the difficulties that they did not encounter in the virtual environment at all.

Users felt that it was more interesting to navigate in the virtual environment than in the Google Street View. They also asked fewer questions to the phone instructor when navigating in the virtual environment. Apart from that, navigation in the virtual environment improved their overall mood, and they also felt happier after the task.

Knowledge transfer and gender differences

All participants were able to recognise the routes from navigation in both the virtual environment and Google Street View. However, one woman did not recall any landmarks from Google Street View, four participants did not place any landmarks from both the virtual environment and Google Street View, one woman did not complete her real world navigation to the virtual environment destination and two women did not navigate the same route to the Google Street View destination in the real world. The findings show that the navigation knowledge was transferred from simulated environments according to the learning objectives, but the level of retention was individually different.

Apart from that, participants recalled more landmarks from navigation in the virtual environment than navigation in the Google Street View. The findings are in line with the opinions of Ruddle et al. [72, 74] that navigation in virtual environments improve spatial knowledge and the use of visible landmarks increase knowledge retention. However, when navigating in the real world, participants took less time to complete the similar Google Street View navigation. Although navigation in the Google Street View was harder than in the virtual environment, the practice allowed them to be more efficient, in the sense of time, in the real world navigation.

When considering gender differences, users' score indicates that men had better spatial and navigational abilities than women. The perception was confirmed in the experiment as men recognised the routes better than women. The findings are in line with what Castelli and his team found [75], when both sexes were asked to recall the spatial knowledge, the men' performance exceeded the women.

Instruction modalities

Users felt that direct companion was easier to use than phone instructor or text on paper for the navigation tasks. The perception was confirmed by their conversation, in which they asked fewer questions when navigating with the direct companion than when navigating with the phone instructor. The task completion time also demonstrates that navigation with the direct companion took less time than navigation with the text on paper. The findings are in line with the literature of collaborative learning in virtual environments and the use of companion to the learning experience, stating that direct collaboration generates better learning environment and communication.

The direct companion was a better instruction modality for navigation due to weaknesses of the other modalities. The phone instructor was poor because the instructions were not clear enough, unable to concentrate because doing three tasks concurrently (listening and understanding the instructions and navigating the route), and challenging in locating in the environment with the instructions given. For text on paper, it was poor due to the difficulty to find the destination without any help.

4.7 Conclusion

The purposes of this study were to investigate the need of a three-dimensional virtual environment to learn a route in the real world, to find a better modality in following the navigation instructions and to examine short-term memory following the task. The study presented here suggests that virtual environment might be a better method of learning a real route in terms of the users' experience and immediate recall of landmarks from the environment than Google Street View. The study also suggests that direct companion is a better instruction modality than phone instructor and text on paper for both environments as users receive a quick and clear response. Therefore, it is concluded that it is possible to learn a route in a virtual environment if the purpose of a digital experience is to enhance landmarks knowledge immediately after navigation and have a pleasurable experience overall. It is also concluded that a direct companion (or direct collaborative learning) provide better instructions for route learning, indicating that it is an excellent method understanding new knowledge.

However, this study has indicated limitations that can be addressed in future. The first limitation is the routes. The different route was tested in each environment (i.e. Route 1 in the virtual environment and Route 2 in the Google Street View), and the participants were asked to learn from both environments. However, it would give different results if each route is tested in each environment, whether users' performance is influenced by the routes or environments. The details of the route might be different regarding buildings, road familiarity etc. Users can learn the same route in the different environment to find differences of the environment or learn the different route in the same environment to see differences of the route. However, a large sample is needed to run this experimental design. The second limitation is prior knowledge of route and use of Google Street View. This study just asked whether they knew the location of the destination. However, some participants might be familiar with the route and might be easier for them to find the destination, although they did not know it in the first place. Furthermore, prior use of Google Street View was not asked in this study that might influence the participants' performance. Some participants might navigate quicker than others as they usually use Google Street View for route planning. Therefore, it would be better if participants are recruited and assigned to a condition according to their knowledge of both route and destination, and also their use of Google Street View.

Further works to be explored in the following study are to expand the study of procedural learning in another area and to investigate whether direct collaborative learning should be fully attended by a coach to improve the learning outcomes.

4.8 End-of-chapter Summary

In short, virtual environments are still a valid platform to learn new knowledge, in particular, procedural learning and to improve learners' skills as it can repeatedly be used. Also, the representations of knowledge and real world setting in virtual environments allow experiential learning that facilitates learners to memorise, recall and apply the knowledge back, especially landmarks knowledge. In any knowledge, direct collaborative learning seems to be a better choice to understand new lessons and also, to avoid misconceptions.

Chapter 5

Study 2

Contents

This chapter investigates further issues which are related to navigation-based procedural learning. In the current study, some of the concepts already identified in Study 1, were refined for ritual learning (Sa'ie). The previous findings indicate that virtual environment is an acceptable delivery method to learn the procedure of route navigation. As such, a full three-dimensional representation with simple gamification was compared with the current teaching method adopted in Malaysia (PowerPoint note). Apart from that, whether collaboration with an inexperienced companion (novice) or an expert companion (coach) had significant advantages, was investigated and the short and long-term transfer of knowledge after learning was tested. Finally, the performance between men and women was compared.

5.1 Introduction

This section describes requirement analysis, background and aim, research hypotheses and terminology of the present study (Study 2).

5.1.1 Requirement Analysis

Following the outcomes in Study 1 (Chapter 4), there is a need to expand the use of full three-dimensional representations for procedural learning. To overcome limitations of the existing applications as discussed in Chapter 3 (see also Table 4.1, Chapter 4), virtual environments still can be used to learn the same ritual, but in a different learning method. Therefore, it is important to develop an improved application for procedural learning, in the context of ritual knowledge. As the previous results also show that the direct collaborative learning positively influenced learners' performance in the route learning, it is also appropriate to investigate whether the same results apply to learning of the Sa'ie ritual which is composed by navigation a route plus performing specific actions. Besides, it is relevant to examine the effects of ritual learning in the virtual environment to learners' memory.

In the current study, a simple serious game of Sa'ie presenting a virtual environment of Mas'a was created and used to examine the efficiency of game-based learning in the ritual learning. Also, the need of a coach was investigated to see whether learners' performance was positively influenced. Apart from that, the efficacy of learners' memory was examined in a short and long-term period, and differences between genders were studied.

5.1.2 Background and Aim

Serious games are games created to fulfil goals rather than for pure entertainment [241, 242]. Nowadays, serious games are utilised in education because it invents new methods that can increase learning standards and quality [243]. Therefore, the present study investigated the components as described in Section 5.1.1 through a game-based learning experiment. Volunteers learned how to perform Sa'ie properly from the serious game or PowerPoint note with or without a coach. They were also asked to recall the knowledge acquisition by performing a few tasks after the learning session and two weeks later. The learning objectives (LO) for this experiment are as follows:

After learning from the method,

1. LO 1: The learner will be able to respond correctly to the questions of a Sa'ie quiz, including the question of the Sa'ie definition
2. LO 2: The learner will be able to draw the route on paper (Post-route recognition task)
3. LO 3: The learner will be able to identify and place real-world landmarks on paper (Landmarks recall and placement task)
4. LO 4: The learner will be able to walk and perform the correct ritual actions required along the route in the real world (Real world navigation task).

The game created in the current study was categorised as a simple serious game, as it did not have complete gamification such as a rewarding system for a correct gameplay. However, the game presented several visually interesting three-dimensional features such as the building of Mas'a itself that engaged them in the learning experience.

5.1.3 Research Hypotheses

Given the literature review conducted in Chapter 2 and discussion in Chapter 3 and 4, four hypotheses were raised as follows:

1. Serious game is a better learning method than the currently used teaching method of Sa'ie (PowerPoint note)
2. Learning with a coach improves users' knowledge more than peer learning with a novice only
3. Learning from a serious game enhance long-term knowledge transfer on landmarks representations
4. Women enjoy learning with a companion more than men.

5.1.4 Terminology

This chapter focuses on visual representations, collaboration, memory recall and gender differences. Given the frequency with which specific terms related to them occur in what follows, in particular, in Section 5.2 to 5.5, the terms will be abbreviated as VE (plural: VEs) - virtual environment, SG - serious game, PPT - PowerPoint note, RW - real world, NC - two novices and a coach, NN - two novices only, ST - short-term (Paper 1), LT - long-term (Paper 2), M - males and F - females.

5.2 Visual Representations

In this section, the visual representations are discussed such as methods for ritual learning and the development of the SG.

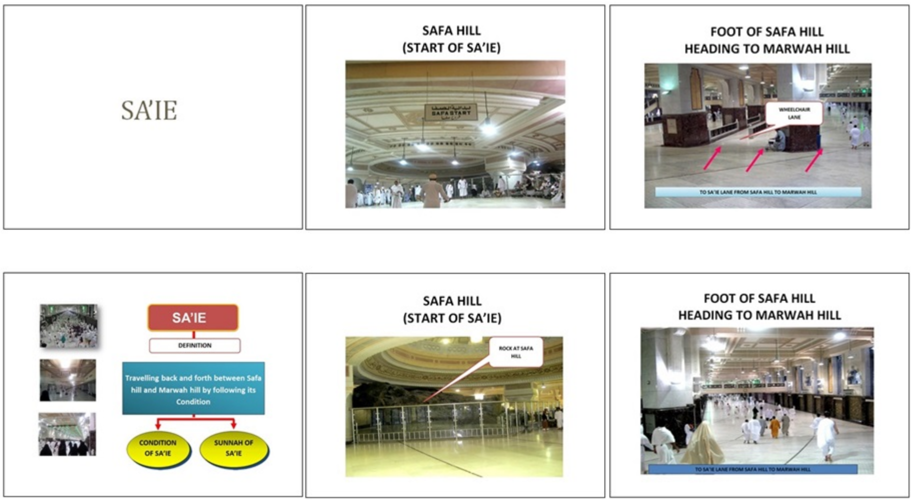


Figure 5.1: PPT used in the experiment

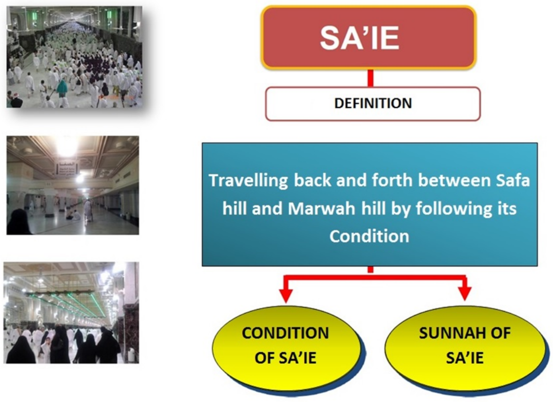


Figure 5.2: Sa'ie definition in the PPT

5.2.1 Learning Methods

Although two different methods were used in the current study, both SG and PPT presented the same contents of how to perform the Sa'ie ritual. For PPT, the note presentation was approximately similar with the note used by Tabung Haji [220], including the pictures of Mas'a and the ritual, except the note was translated into English (Figure 5.1). Also, participants were presented with the definition of Sa'ie at the beginning of the note (Figure 5.2), describing the actual meaning of this ritual.

The same translated note was used in the SG, including the definition of Sa'ie but different ways as outlined in Section 5.2.2.2.

5.2.2 How the Serious Game Was Developed

The development of the SG involved two stages as described in the next sections. The first stage focused on the development of the VE of Mas'a in SketchUp and the second stage was the development of Sa'ie game in the game engine Unity. The same machine as explained in Study 1 (see Section 4.2.3) was used.

5.2.2.1 Development of the virtual environment of Mas'a

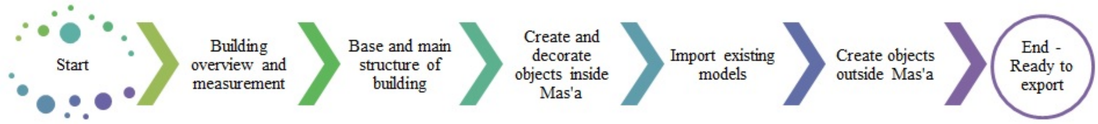
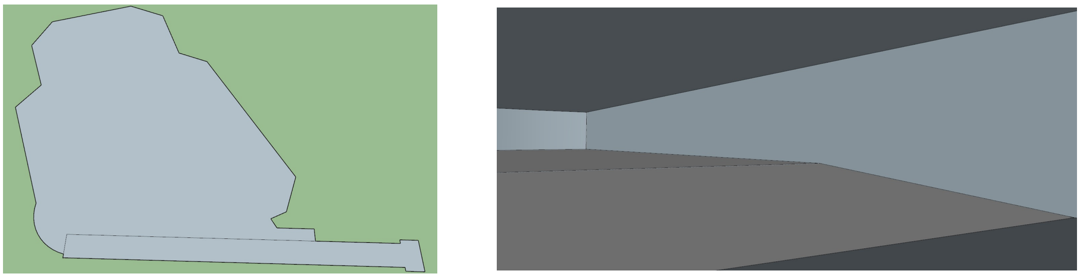


Figure 5.3: Steps in the VE development of Mas'a

As the Sa'ie game was a pilot project, the development just focused on the ground level of Mas'a (see Figure 3.3). Five main steps were involved in developing the VE of Mas'a (Figure 5.3). The first phase was building overview and measurement. The Umrah video and the pictures from Tabung Haji note were reviewed. The actions while performing Sa'ie were also checked. There were six main reference points, for example, hills and Kaabah.



(a) Base of Masjidil Haram

(b) Walls and hill in Mas'a

Figure 5.4: Early developments of VE

The same version of SketchUp as in Study 1 was used (see Section 4.2.3.2). The second step was creating a base of Masjidil Haram and main structures of Mas'a. The base of Masjidil Haram was created based on the floor plan (Figure 5.4a). After that, the main structure of Mas'a was developed, for instance, walls and hills (Figure 5.4b).

The next step was creating and decorating objects inside Mas'a. The examples of objects created in this phase were stairs and posts at both hills. Then, the objects were located at the correct place in the environment. Some objects were decorated to copy the same setting in Mas'a, for example, the design on the posts. As some objects and decoration were the same, it was just created for the first time and then was copied and put in the right place (Figure 5.5).

The fourth step in this phase was importing models from a free 3D object library on the web such as rock for the hill and disabled logo. The rock was resized and duplicated several times to create a big rock. It then was placed in the glass fence area that was

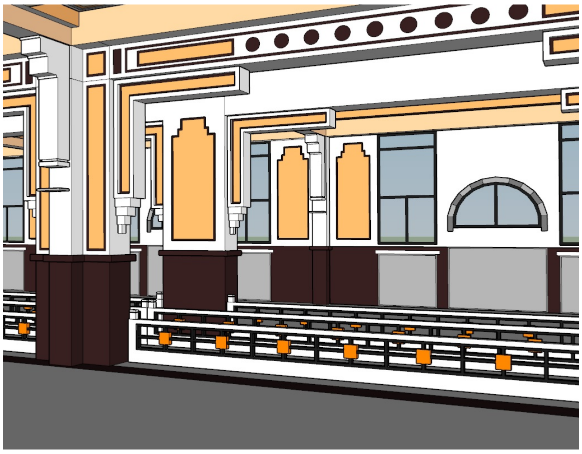
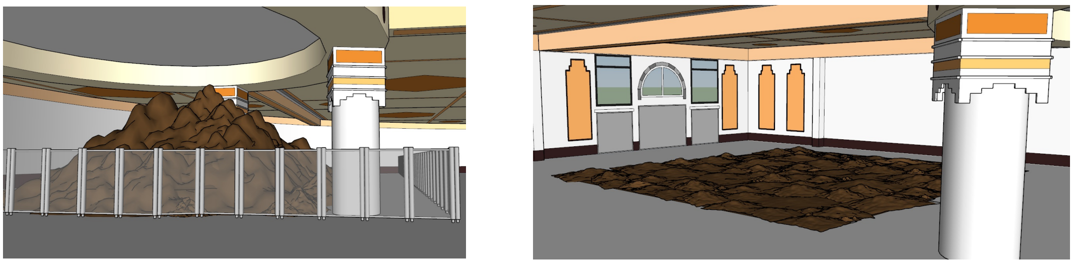


Figure 5.5: Objects creation and decoration



(a) Rock at Safa hill

(b) Rock at Marwah hill

Figure 5.6: Imported models

located in the middle of Safa hill (Figure 5.6a). For Marwah hill, the rock was flattened to replicate the same shape of the original rock and was placed close to the wall (Figure 5.6b).

In the final step, some objects that were located outside Mas'a were created, for example, Kaabah and pathways to connect Mataf and Mas'a. Also, the main structures of the basement and first level were also developed and merged into the structure of the ground level. However, no decoration was done to both levels. In this step, the ground level of Mas'a and objects inside it were rechecked. Also, the whole building of Masjidil Haram was carefully reviewed to make the final adjustment. Finally, the VE of Masjidil Haram, in particular, the ground level of Mas'a was complete and ready to be exported into Unity (Figure 5.7).

5.2.2.2 Development of the Sa'ie game

In the second stage, two main steps were performed. The first step was preparing paperwork of the Sa'ie game development. The paperwork had two major items such as game storyboard and game elements. The storyboard showed the knowledge of the Sa'ie ritual such as definition, Conditions and Options (or *Sunnah*), and also indicated the location to present it in the game, for example, an action indicating 'Reach the foot

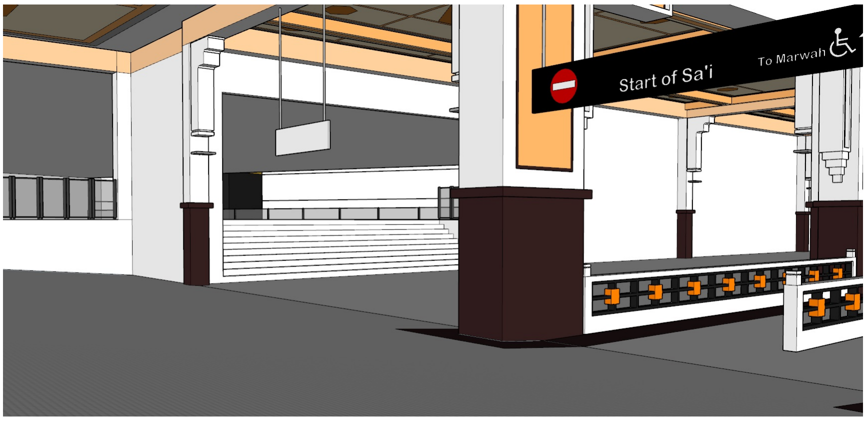


Figure 5.7: Final model of Mas'a in SketchUp

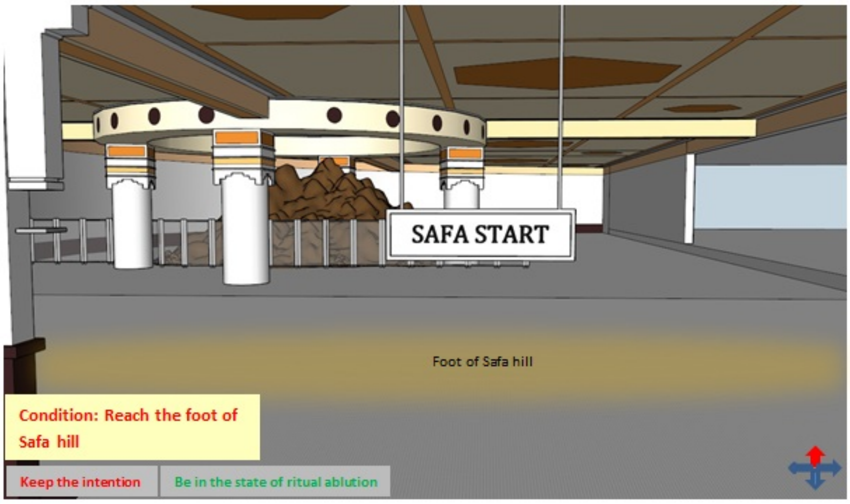


Figure 5.8: A storyboard of the Sa'ie game

of Safa hill' was presented close to Safa hill but before the signpost of 'SAFA START' (Figure 5.8). The paperwork furthermore described the game elements, for example, a counter showing a current round of Sa'ie.

As soon as the paperwork was complete, the development of Sa'ie game in Unity started. It comprised seven steps as showed in Figure 5.9.

The script was created to allow players to navigate in the environment using the four arrow keys on the keyboard or WASD. The UP/W key was used to go forward, the DOWN/S key to go backwards, and the RIGHT/D and LEFT/A keys were for right and left turn respectively. The players were asked to use a mouse to look around in the environment.

Finally, the Unity application of the Sa'ie game was complete (Figure 5.10 - 5.14). Although it was not fully gamified, it contained simple game elements such as 3D blue arrow at eye level and green lights for goals that players had to achieve until the end of gameplay (next direction of movement), sound appeared every time they triggered the green lights as immediate feedback, and round counter for progression of gameplay and learning. It was tested a few times including user testing and test on different sizes of screen.

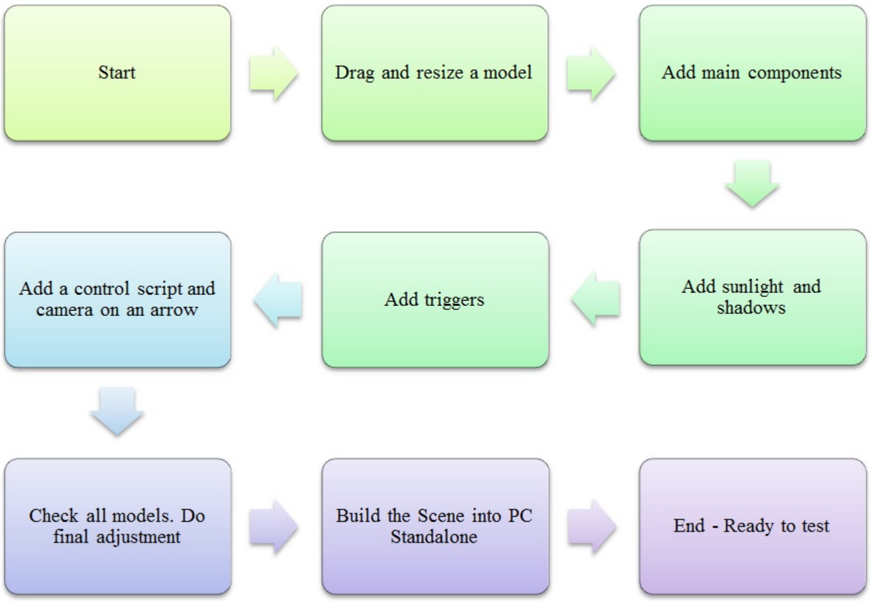


Figure 5.9: Steps in development of Sa'ie game

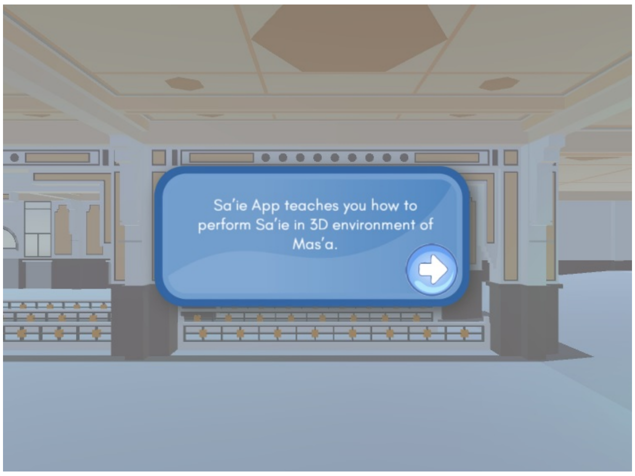


Figure 5.10: SG: Introduction box

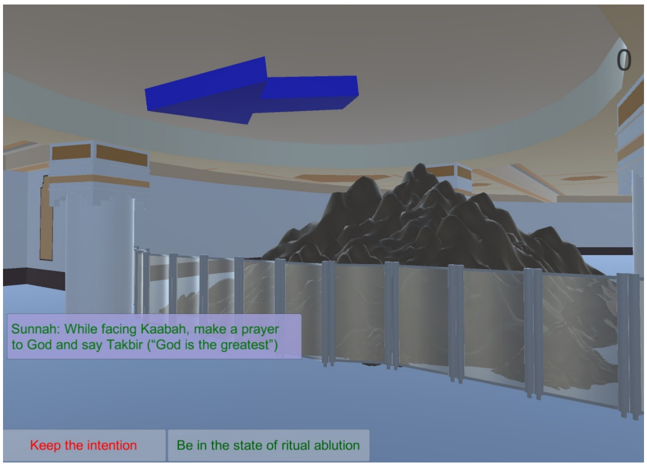


Figure 5.11: SG: The next goal at Safa hill

Figure 5.12: SG: One of the goals, completing round 3 of Sa'ie

Figure 5.13: SG: Walking briskly at the green lights area

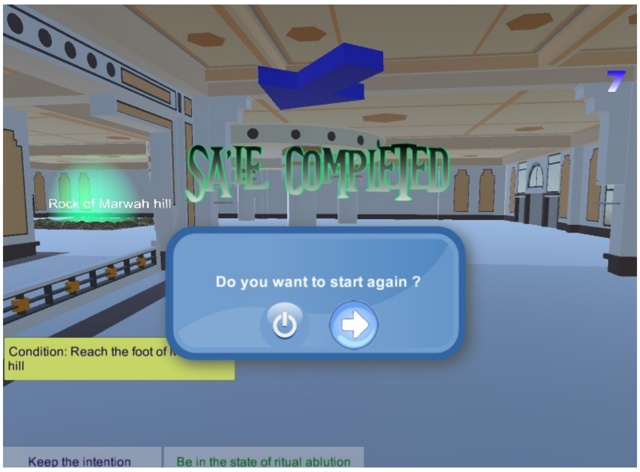


Figure 5.14: SG: The final goal, completing round 7 of Sa’ie

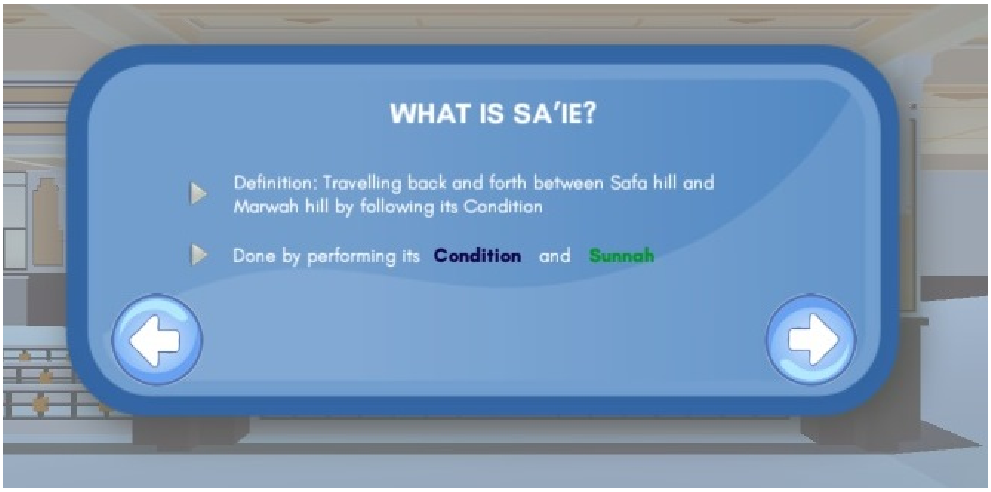


Figure 5.15: Sa’ie definition in the SG

Also, in the Sa’ie game, players were presented with the definition of Sa’ie (Figure 5.15) that was similar to the definition used in the PPT.

5.3 Materials and Method

This section describes four components of materials and method such as participants, experiment design, data collection and questionnaires as well as software and hardware used in the experiment.

5.3.1 Participants

Thirty-two participants were recruited through word of mouth and volunteers mailing list, with an emphasis on having an equal number of women and men (16 for each gender - 50%) (Table 5.1). All volunteers affirmed that they did not have epilepsy and they had not consumed alcohol, drugs or had not taken prescription medication within the last 12 hours before the experiment began. The average age of the participants was 25.28, of which 18 participants (56.25%) fell in the 18 - 24 age category, 12 participants (37.5%) were 25 - 34 age category and the remaining 2 (6.25%) were 35 - 44 age category. All participants (100%) the first language was not English. The language is one of the criteria for inclusion in the study that to ensure people of any language can learn the similar ritual. All participants (100%) also were not colour blind.

Over half of the participants were game players, of which, 20 participants in the sample (62.5%) played video games, while 12 (37.5%) did not play games. Two volunteers (6.25%) played every day, 3 (9.38%) played 5 - 6 times a week, 2 (6.25%) stated they played 1 - 2 times a week, 1 (3.13%) played 1 - 3 times a month, 5 (15.63%) indicated that they played every couple of months, and another 7 participants (21.88%) stated that they played less often. For participating in the experiment, a criterion was that they never performed the real ritual in their lifetime and they did not have any walking limitation.

Table 5.1: Demographic background of participants

Demographic Item		***n***	**%**
Gender	Male	16	50
	Female	16	50
Age category (years old)	18 - 24	18	56.25
	25 - 34	12	37.5
	35 - 44	2	6.25
English as the first language	Yes	0	0
	No	32	100
Colour blind	Yes	0	0
	No	32	100
Playing video games	Yes	20	62.5
	No	12	37.5
Frequency of playing video games	Everyday	2	6.25
	5 - 6 times a week	3	9.38
	1 - 2 times a week	2	6.25
	1 - 3 times a month	1	3.13
	Every couple of months	5	15.63
	Less often	7	21.88
	Do not play	12	37.5

5.3.2 Experiment Design

As the experiment involved two learning methods (SG and PPT) and two collaboration types (NC and NN), four sets of design were produced (Table 5.2). Every set was performed by eight participants.

For collaboration, NC (Novices Coach) type required two novices learn with a coach. The coach in this study was a person who knew about Sa'ie in detail, and s/he performed it previously. The novices learned about the ritual together with help from the coach (e.g. answered questions from the novices). While for NN (Novice Novice) type, two novices learned about the ritual by themselves. If they had any question, they had to sort it out by themselves.

Table 5.2: Four sets of experiment design

	Learning method	**Collaboration**
Set 1	SG	NC
Set 2	SG	NN
Set 3	PPT	NC
Set 4	PPT	NN

SG = Serious game, PPT = PowerPoint note, NC = Novices Coach, NN = Novice Novice

5.3.3 Data Collection, Scoring and Questionnaires

Experiment data were obtained in three sessions such as pre-, during and post- (Table 5.3). In this section, the questionnaires used in the experiment are discussed. Some questions were the same questions as in Study 1 (see Section 4.3.3.1 and 4.3.3.3) and additionally, some relevant questions were added. The scoring elements are also presented here.

In the post-session, participants were asked to answer questions in Paper 1 and 2. Both Paper 1 and 2 comprised the same four tasks such as Sa'ie quiz, landmarks recall and placement, and post-route recognition. However, Paper 1 was administered after the learning session (ST) while Paper 2 was done two weeks later (LT) with a different order of tasks.

5.3.3.1 Pre-session

Background information
Participants were asked to answer some background information such as gender, age, the first language, colour blind, video games playing and the frequency of playing. These background information were asked to check its relationship with another data collected from the experiment.

Spatial and navigational abilities
Participants also rated their spatial and navigational abilities. All seven questions of Hegarty et al. [236] test as in Study 1 was asked, with an additional question. The new question was 'I do not like to explore', and the score ranges from 1 to 5, in which 1 is 'strongly disagree' and 5 is 'strongly agree'.

Immersive tendency
Participants' tendencies to experience presence were also examined. Of the seven

Table 5.3: Experiment sessions

Session	Tasks	Time allocation	Data collection	Tools
Pre	Experiment formalities	**5 min**	–	Details sheet and consent form
	Questionnaire	**5 min**	Background information, spatial and navigational abilities, immersive tendency, mood and Sa'ie definition	Online questionnaire
During	Sa'ie learning	No specific time (**20 min***)	Time, video, conversation and note	SnagIt, Smart Voice Recorder and A4 papers
Post	Questionnaire	**5 min**	Mood, navigation experience and presence	Online questionnaire
	Paper 1	**15 min**	Time, Sa'ie quiz, landmarks recall and placement, and route recognition	Stopwatch and Paper 1 questions
	Physical task (RW navigation)	**5 min**	Time, audio and video	Video recorder
	Questionnaire	**5 min**	Comments	Online questionnaire
	Paper 2	**15 min**	Time, route recognition, landmarks recall and placement, and Sa'ie quiz	Stopwatch and Paper 2 questions

**The maximum time shown from data analysis*

questions of Immersive Tendency Questionnaire [237] in Study 1, only three were used with two additional questions. All five questions were the same as in the original questionnaire, and the score ranges from 1 to 5. The three questions were 'How easily can you switch your attention from the task in which you are currently involved to a new task?' and the score of 1 is 'not easily' and 5 is 'very easily', 'To what extent have you dwelled on personal problems in the last 48 hours?' and the score of 1 is 'not at all' and 5 is 'very much', and 'Do you ever become so involved in doing something that you lose all track of time?' and the score of 1 is 'rarely' and 5 is 'frequently'. The new two questions were 'Do you ever become so involved in a video game that people have problems getting your attention?' and the score of 1 is 'rarely' and 5 is 'frequently', and 'How mentally alert do you feel at the present time?' and the score of 1 is 'very inattentive' and 5 is 'very alert'.

Moods

Participants were then asked about their current moods.The same reduced version of the Brief Mood Introspection Scale (BMIS) [238, 239] as in Study 1 was used.

Sa'ie definition
To establish the baseline knowledge of the Sa'ie ritual, they were asked whether they knew the definition of Sa'ie (see Question 1). If they knew, they were asked to choose the answer from multiple choices as presented in Question 2. A score of one was given if they chose the correct answer and a score of zero if they stated that they did not know or they picked a wrong answer.

1. Do you know what Sa'ie is?

   (a) Yes
   (b) No

2. What is Sa'ie?

   (a) Travelling from Safa hill to Marwah hill by following its Conditions
   (b) Travelling from Marwah hill to Safa hill by following its Conditions and Options (*Sunnah*)
   (c) Travelling back and forth between Safa hill and Marwah hill by following its Conditions
   (d) Travelling back and forth between Safa hill and Marwah hill by following its Conditions and Options (*Sunnah*)

5.3.3.2 During session (Serious game and PowerPoint note learning)

Learning time
While learning from SG and PPT, the time was recorded.

Serious game learning video and audio
For learning from SG, playing video and audio were also recorded. The recording was used to study participants' performance while navigating such as difficulties they faced, their behaviours while learning, and advantages and disadvantages of SG.

Conversation
For both SG and PPT, the entire conversation while learning was recorded to determine the number of questions.

Note taking
Participants also were given blank A4 papers to write down any note while learning. The notes taken were analysed to see similarities amongst participants.

5.3.3.3 Post-session

Moods
Participants were asked again about their current moods. The same reduced version of the Brief Mood Introspection Scale (BMIS) [238, 239] as in Study 1 was used.

Learning experience
Also, participants were asked to evaluate their learning experience. By referencing the navigation questionnaire from Ruddle et al. [72], five questions of learning experience were designed, and the score ranges from 1 to 5. The questions were 'How interesting was your Sa'ie learning?' and 'How interesting was your learning method (PPT note or Sa'ie game)?' and for both questions, the score of 1 is 'very boring' and 5 is 'very interesting', 'Did the learning method (PPT note or Sa'ie game) help you to learn and understand Sa'ie better?' and the score of 1 is 'not at all' and 5 is 'a lot', 'Did you enjoy learning Sa'ie with your companion?' and the score of 1 is 'very boring' and 5 is 'very enjoyable', and the final question was 'Did the collaborative learning help you to learn and understand Sa'ie better?' and the score of 1 is 'very useless' and 5 is 'very helpful'.

Presence
Moreover, a reduced version of the Presence Questionnaire [237] was used to enquire about presence during learning. In the current study, only two of the seven questions of Presence Questionnaire [237] in Study 1 were used with two additional questions. All four questions were same as in the original questionnaire, and the score ranges from 1 to 5. The same questions as in Study 1 were 'How much did the visual aspects of the environment involve you?' and the score of 1 was 'not at all' and 5 was 'very much', and 'How completely were you able to actively search the environment using vision?' and the score of 1 was 'not at all' and 5 was 'completely'. The additional questions were 'How compelling was your sense of objects moving through space?' and the score of 1 was 'very boring' and 5 was 'very compelling', and 'How well could you examine objects from multiple viewpoints?' and the score of 1 was 'very poor' and 5 was 'very well'.

Paper 1 and 2 - Sa'ie quiz
For testing of the knowledge acquired during learning, participants were asked to answer the Sa'ie quiz, which was questions on Conditions and Options of Sa'ie. Nine questions were posed in both Paper 1 and 2, including the question of the Sa'ie definition (see Question 2 of the Sa'ie definition, in Section 5.3.3.1). However, in the Paper 1, there were two extended questions asking participants to justify their previous answer (see Appendix C for all questions). Also, the order of questions in the Paper 2 was changed. For scoring the nine questions, one point was assigned for each correct answer and no score given to the extended questions. Thus, the maximum score achievable was nine.

Paper 1 and 2 - Landmarks recall and placement
Participants were also asked to do landmarks recall and placement task. The same question of landmarks recall and placement as in Study 1 was asked [240]. The elements for scoring the landmarks recall was also same. However, for landmarks placement, the task was scored based on two elements: the correct location of landmarks (a score of one was given if they marked all landmarks they had recalled correctly; a score of the number of landmarks placed correctly was divided by the total of landmarks recalled, was given if only some landmarks were marked; and a score of zero was given if no landmark was indicated) and recurrence of erasing lines (1 point for no hesita-

tion, 0.5 for up to three lines, a score of zero for more than three lines). The maximum score achievable was two. Also, for landmarks recall, participants were asked to list it on paper, instead of listing it on the computer screen.

Paper 1 and 2 - Post-route recognition
Also, participants were asked to perform post-route recognition task.The same question of post-route recognition as in Study 1 was asked [240], but the elements for scoring were different. For this study, the score given for the route drawing was based on four elements: the start point (1 point), the end point (1 point), the correct labelling of the start and the end point (1 point), and the route accuracy (1 point) in which they acknowledged that they had to walk through the route seven times. The maximum score possible was four.

Physical task time, audio and video (Real world navigation)
They moreover were asked to do the physical task that required them to perform all actions of Sa'ie while navigating the route between two hills at a small indoor area. They were audio and video recorded while performing the physical task. The performance time was also recorded. Their performance accuracy was scored based on two major elements: 1) Conditions, these were nine possible actions (9 points) (e.g. begin the ritual from Safa hill) and 2) Options, there were ten possible actions (10 points) (e.g. go over the hill of Safa) (see Section 3.3.2.1 and 3.3.2.2 for all actions). The maximum score for this task was nineteen.

Comments
Lastly, participants were also provided with a free text comment section.

5.3.4 Software and Hardware

As the experiment involved two novices at the same time, two desks with a machine (a HP Compaq laptop and a desktop) were provided (Figure 5.16). Both machines had a good connection to the web to run the online questionnaire. The same equipment as in Study 1 was used to display the output and control the game-based learning (see Section 4.3.4). SnagIt application was installed on the same laptop and was used to record the playing video (Table 5.3).

Two sets of notes were given to participants who learned from PPT. The same notes were also given to the coach who taught participants. A Samsung mobile phone running Smart Voice Recorder application was used to record a conversation while learning. The time of recorded conversation was considered as learning time. Participants were also given some blank A4 papers. Figure 5.17a shows the area for the learning task in the experimental room.

The Paper 1 was given to every participant after learning. The stopwatch in the phone was used to record the time taken by participants to answer the Paper 1. Two Samsung mobile phones were used for stopwatch, one for each participant. The same Samsung mobile phone was used to record participants' video while performing the physical

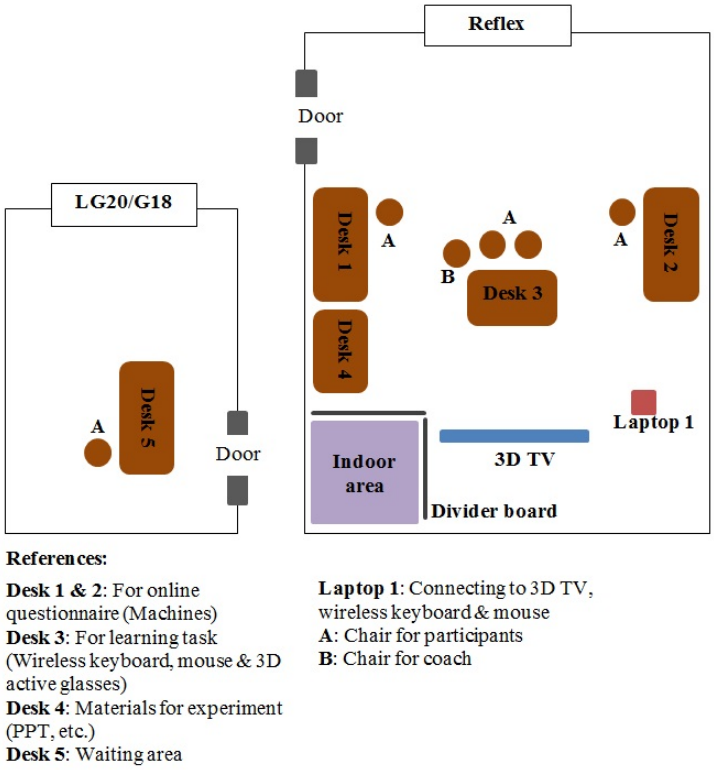
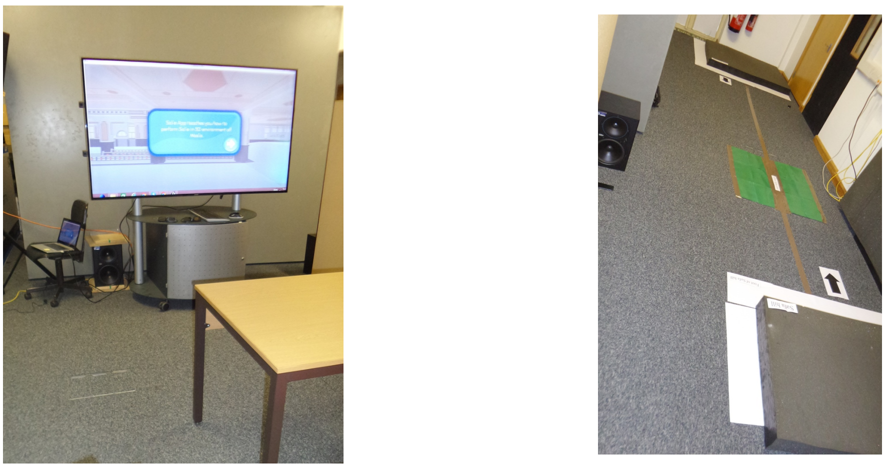


Figure 5.16: Layout of the experimental room

task in the indoor area (Figure 5.17b). The indoor area was covered by divider boards to avoid participants seeing it from the beginning of the experiment.

Two weeks later, the Paper 2 was given to participants. Their answering time was recorded using the stopwatch in the Samsung mobile phone.



(a) For learning task

(b) Indoor area

Figure 5.17: Experimental room

5.4 Procedure

Table 5.3 also shows the procedure of experiment with time allocation. The overall time for participants to complete the whole experiment was 60 minutes. After two weeks, 15 minutes were given to answer the Paper 2.

The same experiment formalities as in Study 1 were administered (see Section 4.4). They then answered the questions as described in Section 5.3.3.1.

Following, they learned how to perform the Sa'ie ritual according to assigned experiment set. Participants also were given blank A4 papers to write down any notes while learning. No specific time limit was given for learning the ritual.

After performing the learning task, they answered the questions as discussed in Section 5.3.3.3. Then, they were asked to do the physical task. While one participant was doing it, the other participant was asked to wait in a different room. Lastly, participants were also asked to provide any comment about the experiment. Participants were provided with some light refreshment after completing the task. After two weeks, they were met again to answer the Paper 2.

Two different learning methods were used in the experiment; however, each method presented the same contents of Sa'ie knowledge. Participants, who used SG, learned about Sa'ie while playing the game, while those who used PPT, read it to know about Sa'ie. Whether they learned with or without the coach, they were encouraged to discuss while learning. When learning from SG, a keyboard and a mouse were used to move and look around in the virtual Mas'a. As two novices learned together, they were asked to discuss how and who would handle the devices for navigation (e.g. the same person handled both devices until the end). However, for NC condition, a coach was not allowed to handle the devices. In this study, controlling the navigation devices might influence Sa'ie learning because a participant who controls it might engage with the environment more than the other participant. S/he fully focuses on the content while navigating that helps him/her to understand and remember better.

5.5 Results

This section discusses results from the experiment such as information of all participants before the learning task and comparison of four major factors: 1) learning methods between SG and PPT, 2) collaborative learning between NC and NN, 3) memory recall between ST and LT, and 4) gender differences. This section moreover describes observations of participants' behaviour from the experiment.

As in Study 1, the data distribution was checked, and the same version of SPSS was used to analyse the numerical results (see Section 4.5).

5.5.1 Pre-Learning Information

The following results explain some information of participants before performing the learning task, for example, spatial and navigational abilities, immersive tendency, overall mood before doing the learning task and Sa'ie definition that measured participants' pre-knowledge on Sa'ie.

5.5.1.1 Spatial and navigational abilities

A spatial and navigational abilities test was administered. The overall average score on all the questions test was 3.54/5, demonstrating that most participants felt they had an average or above average abilities. In the sample, 10 participants (31.25%) felt they were overall very good, 16 (50%) reported having good abilities, and the remaining 6 (18.75%) felt they were poor.

5.5.1.2 Immersive tendency

Participants also took an immersive tendency test before the learning task. The overall average score was 3.07/5, suggesting that the majority of the participants felt they had an average tendency. Of the 31, 1 participant (3.13%) reported that he was overall very good, 23 (71.88%) felt that they had a good tendency and the remaining 8 (25%) stated having a poor tendency.

5.5.1.3 Overall mood before the learning task

Before performing the learning task, participants were asked about their overall mood. The overall average score was 3.09/4. The results demonstrate that participants' mood was mixed in which 10 participants (31.25%) felt very pleasant, 16 (50%) felt pleasant, 5 (15.63%) felt unpleasant, and one (3.13%) felt very unpleasant.

5.5.1.4 Accuracy of the Sa'ie definition

To check participant's knowledge before the learning session, they were asked about the definition of Sa'ie. Of the 32 participants, 8 (25%) answered it correctly, 19 (59.38%) answered it wrongly, and the remaining 5 (15.63%) stated that they did not know the definition.

5.5.2 Comparison of Learning Methods between Serious Game and PowerPoint Note

This section describes a comparison of learning methods between SG and PPT, considering various results such as spatial and navigational abilities, mood, learning experience, presence, and short-term and long-term memory recall.

5.5.2.1 Spatial and navigational abilities

The total score of spatial and navigational abilities between SG and PPT participants was compared, however, there was no significant difference ($U = 111.5$, $p = .532$) (Table 5.4). When comparing each item in the abilities test, the results show that the SG participants significantly had a better memory for where they left things than PPT participants (U = 72.5, p = .029*) (Table 5.4). Of the 16 participants in the SG group, 10 (62.5%) agreed that they had a good memory. However, only 5 of the 16 PPT participants (31.25%) considered themselves having a good memory.

Table 5.4: Spatial and navigational abilities test (SG vs PPT)

	Average	
	SG	**PPT**
Total score of spatial and navigational abilities	3.61	3.48
Item 1: I have a good memory for where I left things	3.69	2.88

**p <.05; Score ranges from 1 - 5, in which 1 = very poor and 5 = very good for total score, and 1 = strongly disagree and 5 = strongly agree for item 1*

5.5.2.2 Moods

Mood differences between pre- and post-learning for both SG and PPT groups were compared. The results of pre- and post-overall mood reveal that learning from the SG significantly improved participants' mood (W = 0, p = .014*) (Table 5.5). Six of the 16 participants (37.5%) indicated that they felt more pleasant after learning from the SG. In the comment section, they expressed that learning Sa'ie from the SG was very fun because it introduced an entertaining style to learn Sa'ie which was more different than a normal lecture. However, after learning from the PPT, no significant difference was found for overall mood (W = 2, p = .564).

Table 5.5: Pre- and post-overall mood (SG and PPT)

	Average	
Overall Mood	**Pre**	**Post**
SG	2.94	3.31
PPT	3.25	3.31

**p <.05; Score ranges from 1 - 4, in which 1 = very unpleasant and 4 = very pleasant*

Learning Sa'ie from the SG also significantly increased participants' happiness (W = 0, p = .008*) (Table 5.6). Of the 16, 7 participants (43.75%) felt happier after the learning session. Similarly, the PPT participants significantly felt happier (W = 0, p = .025*) in which 5 out of the 16 participants (31.25%) improved the happy score after the learning task. These findings, therefore, suggest that learning a procedure of ritual may change users' mood, to be happier, despite means of knowledge presentation.

No significant difference was found for participants' tired or fed up scores before and after both SG and PPT learning tasks. However, a woman (6.25%) who learned from the SG changed her frustration level from 'I definitely feel fed up' to 'I definitely do not feel fed up' following the learning task. The comment section reported that the Sa'ie

Table 5.6: Pre- and post-happy mood (SG and PPT)

	Average	
Mood: Happy	**Pre**	**Post**
SG	2.94	3.38
PPT	3.25	3.56

**p <.01 or *p <.05; Score ranges from 1 - 4, in which 1 = definitely do not feel and 4 = definitely feel*

learning was a pleasant experience for her and she also found that the SG was very informative.

Also, the findings of the rise in users' moods after learning from the SG, that portrayed a virtual environment of Mas'a, support the similar outcomes in Study 1 (see Section 4.5.3.4). The results also reveal that route learning in the virtual environment improved users' moods, both overall and happy mood.

5.5.2.3 Learning experience

The learning experience between SG and PPT from users' self-reported score was compared. It is apparent that the SG was significantly more interesting than PPT (U = 41, p = .000*) (Table 5.7). All 16 SG participants rated 'very interesting' or 'interesting'; in particular, 14 participants (87.5%) chose 'very interesting' and 2 (12.5%) selected 'interesting'. However, of the 16 who learned from PPT, only 4 (25%) indicated that the PPT was very interesting. Finally, 1 participant (6.25%) who was a woman considered PPT as very boring.

The findings that the SG was an interesting learning method is also consistent with the results in Study 1 (see Section 4.5.3.2). The results of the former study indicate that virtual environment was an interesting environment to learn a real route.

Table 5.7: Interesting method (SG vs PPT)

	Average	
	SG	**PPT**
How interesting was your learning method?	4.88	3.69

**p <.001; Score ranges from 1 - 5, in which 1 = very boring and 5 = very interesting*

Furthermore, there was a significant difference between SG and PPT to the question: 'Did the learning method help you to learn and understand Sa'ie better?'. The results show that the SG was more helpful than the PPT (U = 60 p = .004*) (Table 5.8). Of the 16 participants, 12 (75%) considered the SG helped them a lot, however, only 4 participants (25%) out of the 16 rated that the PPT helped them a lot.

Most of those who rated the SG as an interesting and helpful method, commented that

Table 5.8: Helpful method (SG vs PPT)

	Average	
	SG	PPT
Did the learning method help you to learn and understand Sa'ie better?	4.75	4.13

**p <.01; Score ranges from 1 - 5, in which 1 = very useless and 5 = very helpful*

the SG was an innovative approach to learning how to perform Sa'ie, in particular for the younger generation as it was the same as playing video games. Moreover, it was fun and made the lesson simpler but useful.

5.5.2.4 Short-term memory recall

The following sections illustrate the results of memory recall that was tested after the learning task. For example, the accuracy of the Sa'ie definition, Sa'ie quiz, post-route recognition and landmarks recall.

Accuracy of the Sa'ie definition
The difference of the definition accuracy between pre- and post-session (Paper 1) after learning from the SG and PPT was compared and the results show that there was a significant difference ($U = 64$, $p = .005$*) (Table 5.9). In particular, there is the following relationship:

PPT-Paper 1 >SG-Paper 1 >SG-Pre >PPT-Pre

PPT participants answered the most accurate after the learning session. It is followed by SG participants after learning and subsequently, SG participants before the learning task. However, before learning, PPT participants answered the most inaccurate.

Table 5.9: Accuracy difference between pre- and post-question (SG vs PPT)

	Average mark	Difference of the definition accuracy between
SG-Pre	0.31	0.19
SG-Paper 1	0.38	
PPT-Pre	0.19	0.69
PPT-Paper 1	0.75	

**p <.01; Higher value indicates more mark obtained with the maximum mark of 1*

The average mark of the definition accuracy before learning from the SG was 0.31. After the learning task, the SG participants obtained the average mark of 0.38. Before learning from the PPT, the average mark of definition accuracy was 0.19. However, after learning from PPT, they achieved a higher average of 0.75. The results reveal that participants grasped the knowledge better after learning from the PPT, with the average difference of 0.69. Whereas, the average difference between before and after learning from the SG was nearly the same, in which after learning, participants gained on average of 0.19 more than before learning. Given that all participants answered the same question of the Sa'ie definition, these findings demonstrate that participants were more accurate on the Sa'ie definition after learning from the PPT than learning from the SG.

After learning from the PPT, of the 16 participants, 10 (62.5%) answered the definition question more precise than in the pre-question. However, after learning from the SG, only 2 of the 16 participants (12.5%) answered more accurate than before learning. Unexpectedly, one man (6.25%) after learning from the PPT responded to the question wrongly although he did well in the pre-session. The comment section reported that the PPT was not so relevant for him in this modern age because it was not interactive. Likewise, one woman (6.25%) after learning from the SG answered it incorrectly while she responded to the same question correctly in the pre-session.

Besides, the comparison results of the definition accuracy in Paper 1 between SG and PPT participants indicate that after learning, participants who learned from the PPT significantly answered the question more precise than those who learned from the SG (U = 80, p = .035*) (Table 5.10). Twelve out of the 16 PPT participants (75%) answered the question correctly; however, only 6 of the 16 participants (37.5%) who learned from the SG answered it accurately.

Table 5.10: Sa'ie definition after learning (SG vs PPT)

	Average	
	SG	**PPT**
Sa'ie definition mark	0.38	0.75

**p <.05; Higher value indicates higher mark obtained with the maximum mark of 1*

Sa'ie quiz

The total mark of the Sa'ie quiz was compared between SG and PPT participants. The results present that after learning, participants who learned from the PPT significantly gained more marks than those who learned from the SG (U = 61, p = .008*) (Table 5.11). Of the 16 participants in each group, 10 participants (62.5%) who learned from the PPT acquired the maximum mark (9/9) whereas, in SG group, 3 participants (18.75%) only obtained the maximum mark, suggesting that learning Sa'ie from the PPT encouraged learners to perceive the knowledge more comprehensive although the SG was significantly more interesting according to users' score, see Section 5.5.2.3.

Moreover, in the comment section, some participants mentioned that the PPT provided useful information about Sa'ie. It also included several pictures that showed the environment, although they agreed that they could not visualise the environment properly and the learning was not fun.

Table 5.11: Quiz mark after learning (SG vs PPT)

	Average	
	SG	**PPT**
Total mark of Sa'ie quiz	6.75	8.19

**p <.01; Higher value indicates more mark obtained with the maximum mark of 9*

Post-route recognition

The comparison results of post-route recognition between SG and PPT participants reveal that after learning from the PPT, participants significantly drew the Sa'ie route more precise than those who learned from the SG (U = 66.5, p = .005*) (Table 5.12). Of the 16 participants in each group, everyone but one (15/16 - 93.75%) who learned from the PPT gained the maximum score (4/4) whereas, in SG group, just 7 participants (43.75%) got the maximum score. The results moreover show that the lowest score in the PPT group was 1.14, which was the score of the participant who did not gain the maximum score; however, in the SG group, the lowest score was 0.29 out of 4. These findings also confirm the results discovered in Section 5.5.2.4 - Accuracy of Sa'ie definition and Sa'ie quiz.

Table 5.12: Route recognition (SG vs PPT)

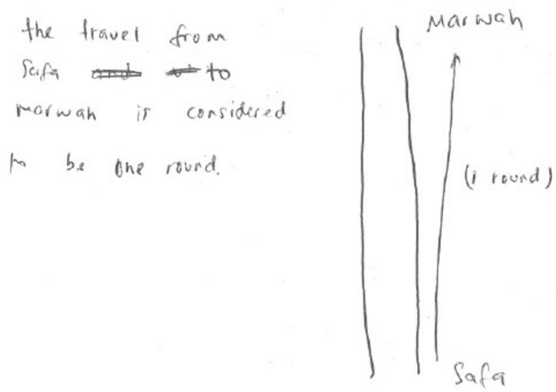
	Average	
	SG	**PPT**
Total mark of route recognition	2.84	3.82

**p <.01; Higher value indicates more score acquired with the maximum score of 4*

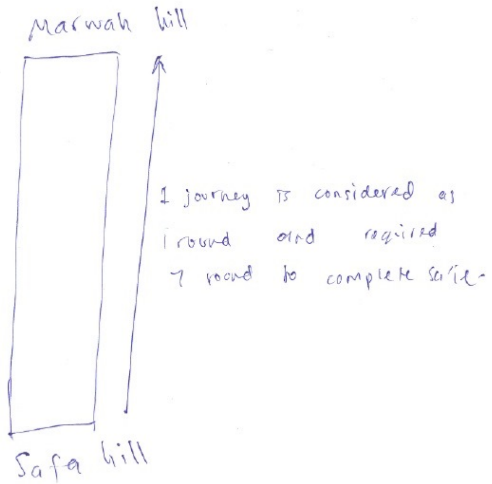
The participant in the PPT group, who did not get the maximum score for post-route recognition task, also did not obtain the maximum score for the same task two weeks later (Figure 5.18). He moreover recalled the landmarks less than average. However, interestingly, he obtained the maximum score for the Sa'ie quiz (9/9), both in the Paper 1 and Paper 2 (two weeks later).

Landmarks recall

The total of landmarks between SG and PPT participants after the learning task was compared and the results show that participants who learned from the SG significantly recalled more landmarks than PPT participants (U = 69.5, p = .021*) (Table 5.13). Considering the PPT average as a baseline, 10 of the 16 participants (62.5%) who learned from the SG recalled more than five landmarks, with the maximum number of nine. However, of the 16 participants who learned from the PPT, only 3 (18.75%) recalled more than five landmarks, with the maximum number of seven. For both groups, the lowest number of landmarks recalled by participants was the same, which four landmarks. Besides, in the comment section, two participants reported that learning from the SG made them remember many things, for example, the most important points in the area, as they paid full attention to surroundings.



(a) Paper 1



(b) Paper 2

Figure 5.18: Route recognition by a participant in the PPT group

Furthermore, the finding that users recalled more landmarks from the SG is similar to the results in Study 1 (see Section 4.5.3.6). The results indicate that participants who learned the route from the virtual environment recalled more landmarks than those who learned from the Google Street View.

Table 5.13: Landmarks recalled after learning (SG vs PPT)

	Average	
	SG	**PPT**
Total of landmarks recalled	6	5

**p <.05; Higher value indicates more landmarks were recalled*

5.5.2.5 Long-term memory recall

In this section, the results of memory recall that was administered after two weeks of the learning task are presented, in particular, landmarks recall.

Landmarks recall
As in Section 5.5.2.4 - Landmarks recall, the total of landmarks after two weeks was compared. Likewise, learning from the SG significantly encouraged the participants to recall more landmarks than learning from the PPT, even two weeks later (U = 73.5, p = .031*) (Table 5.14), indicating that learning in a virtual environment, with representations of 3D objects, stimulated learners' memory to remember more landmarks longer, at the minimum of two weeks.

The average of landmarks recalled by the PPT participants was 4.69. Using this average as a baseline, 7 of the 16 SG participants (43.75%) and 3 of the 16 PPT participants (18.75%) recalled landmarks more than the PPT average, with the maximum number in the SG group was eight and in the PPT group was six. Of those 7 and 3, 5 SG and 2 PPT participants were the same participants who recalled more landmarks after the learning tasks. Interestingly, in the SG group, a woman who recalled the maximum number of landmarks two weeks later (eight) was the same participant who recalled the maximum number after the learning task (nine) (Figure 5.19). After two weeks, the lowest number of landmarks recalled by the SG participants was still same as after learning (four). However, the minimum number in the PPT group reduced to three landmarks.

In the light of results in Section 5.5.2.4 - Landmarks recall, the number of landmarks recalled by participants decreased after two weeks of learning session (Table 5.13 and 5.14).

Table 5.14: Landmarks recalled two weeks later (SG vs PPT)

	Average	
	SG	**PPT**
Total of landmarks recalled	5.50	4.69

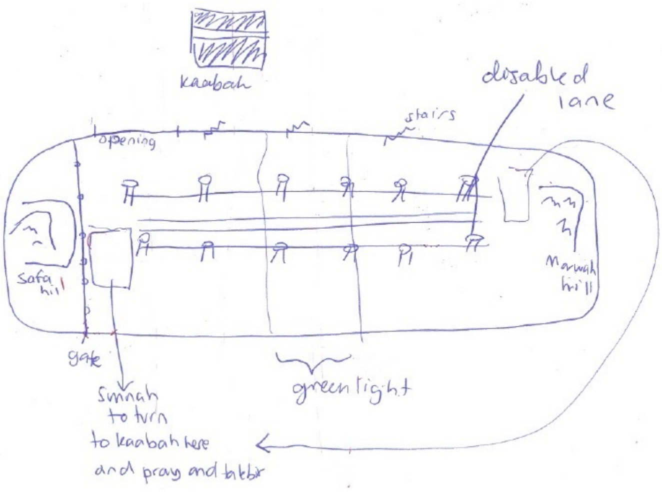
**p <.05; Higher value indicates more landmarks were recalled*

5.5.3 Comparison of Collaboration between Novices Coach and Novice Novice

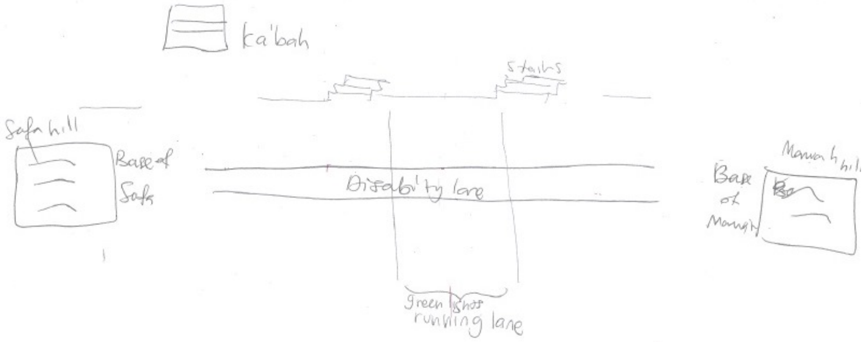
In this section, some comparison results of a collaboration between NC and NN are presented. For instance, the results on mood, conversation while learning the Sa'ie ritual, physical task, short-term and also long-term memory recall.

5.5.3.1 Moods

Mood differences between pre- and post-learning for both NC and NN groups were compared. The results of pre- and post-overall mood show that learning with the coach



(a) Paper 1



(b) Paper 2

Figure 5.19: Highest landmarks recalled by a woman

significantly improved participants' mood (W = 0, p = .014*) (Table 5.15). Six of the 16 participants (37.5%) reported that they felt more pleasant after learning Sa'ie with the coach. However, for NN participants, there was no significant difference between pre- and post-overall mood (W = 2, p = .564), although there was an increase in post-mood. In the comment section, one participant in the NC group mentioned that learning with the coach enhanced the mood of learning in positive ways.

Table 5.15: Pre- and post-overall mood (NC and NN)

	Average	
Overall Mood	**Pre**	**Post**
NC	3	3.38
NN	3.19	3.25

**p <.05; Score ranges from 1 - 4, in which 1 = very unpleasant and 4 = very pleasant*

Learning with the coach also significantly increased participants' happiness (W = 0, p

= .008*) (Table 5.16). Out of the 16, 7 participants (43.75%) felt happier after learning Sa'ie with the coach. In the same way, participants in the NN group significantly felt happier (W = 0, p = .025*), although learning Sa'ie without the coach. Five of the 16 NN participants (31.25%) improved their happy score after the learning session. These two results thus indicate that regardless of who learned with them, the participants tend to be happier after learning a procedure of ritual.

Table 5.16: Pre- and post-happy mood (NC and NN)

	Average	
Mood: Happy	**Pre**	**Post**
NC	3	3.44
NN	3.19	3.5

**p <.01 or *p <.05; Score ranges from 1 - 4, in which 1 = definitely do not feel and 4 = definitely feel*

Besides, the results of pre- and post-tired mood present after learning, participants in the NN group felt significantly less tired (W = 0, p = .02*) (Table 5.17). Six of the 16 participants (37.5%) decreased the tiredness level after learning with their companion who was also the novice. However, after learning with the coach, no significant difference was found for the same mood (W = 8, p = .257), although there was a drop in the post-mood.

Table 5.17: Pre- and post-tired mood (NC and NN)

	Average	
Mood: Tired	**Pre**	**Post**
NC	2.56	2.38
NN	2.69	2.25

**p <.05; Score ranges from 1 - 4, in which 1 = definitely do not feel and 4 = definitely feel*

No significant difference was found for participants' fed up score before and after learning with their companion, either coach or novice. However, a woman (6.25%) who learned with the coach changed her frustration level from 'I definitely feel fed up' to 'I definitely do not feel fed up' after the learning task. She was the same participant in the SG group who decreased the frustration level, see Section 5.5.2.2.

5.5.3.2 Conversation while learning

The total number of questions asked by participants during the learning task was compared. The results indicate that participants who learned with the coach asked significantly more questions than those who learned with the novice (U = 26, p = .000*) (Table 5.18). The highest number of questions asked in the NC group was 38, but in the NN group, it was only 10. Surprisingly, of the 16 participants in the NN group, 4 (25%) did not ask any questions at all during the learning session. In the NC group, the lowest number of questions asked by participants was 5. The findings may suggest that coach involvement allowed novices to raise more questions and therefore, there was an increase in communication.

Table 5.18: Questions asked during learning session (NC vs NN)

	Average	
	NC	**NN**
Total number of questions	12.88	4.25

**p <.001; Higher value indicates more questions were asked*

5.5.3.3 Physical task

The performance of physical task after the Sa'ie learning was scored and compared between NC and NN participants. The results show that participants who learned with the coach significantly performed better than those who learned with the novice ($t(30) = -2.981$, $p = 0.006$*) (Table 5.19). Considering the NC average as a baseline (13.56/19), 7 of the 16 participants (43.75%) who learned with the coach gained the performance score above the NC average, however for NN group, of the 16 participants, only 2 (12.5%) obtained the performance score above the NC average. The lowest score in the NC group was 9.94/19, but in the NN group, it was 7.48/19.

Table 5.19: Physical task performance (NC vs NN)

	Average	
	NC	**NN**
Physical task score	13.56	11.57

**p <.01; Higher value indicates more score obtained with the maximum score of 19*

5.5.3.4 Short-term memory recall

The following sections demonstrate the results of memory recall that was tested after the learning task such as accuracy of the Sa'ie definition and Sa'ie quiz.

Accuracy of the Sa'ie definition
The comparison results of the definition accuracy between NC and NN participants exhibit that after learning, participants who learned with the coach significantly answered the definition question more precise than those who learned with the novice ($U = 80$, $p = .035$*) (Table 5.20). Twelve out of the 16 participants (75%) in the NC group answered the question correctly. However, only 6 of the 16 participants (37.5%) in the NN group responded to the same question accurately.

Sa'ie quiz
The total mark of the Sa'ie quiz was compared between NC and NN participants, and the results reveal that after the learning session, participants who learned with the

Table 5.20: Sa'ie definition after learning (NC vs NN)

	Average	
	NC	**NN**
Sa'ie definition mark	0.75	0.38

**p <.05; Higher value indicates more mark obtained with the maximum mark of 1*

coach significantly obtained more marks than those who learned with the novice (U = 69.5, p = .021*) (Table 5.21). Of the 16 participants in each group, 9 participants (56.25%) who learned with the coach acquired the maximum mark (9/9) whereas, in the NN group, 4 participants (25%) only gained the maximum mark.

Table 5.21: Quiz mark after learning (NC vs NN)

	Average	
	NC	**NN**
Total mark of the Sa'ie quiz	8.19	6.75

**p <.05; Higher value indicates more mark obtained with the maximum mark of 9*

Furthermore, in the comment section, a few participants stated that learning with the coach helped them to understand Sa'ie better, in particular, how to perform the ritual with all actions, both Conditions and Options. Therefore, the findings of the quiz and participants' comments support the outcomes in Section 5.5.3.3 and 5.5.3.4 - Accuracy of the Sa'ie definition, indicating that learning with the coach, developed better knowledge delivery and acquisition, as well as improved learners' performance either physical or mental.

5.5.3.5 Long-term memory recall

In this section, the results of memory recall that was administered after two weeks of learning the task are discussed, for example, the Paper 2 answering time, the accuracy of the Sa'ie definition and the Sa'ie quiz.

Paper 2 answering time

The time to answer all questions in the Paper 2 was compared between NC and NN participants. The results indicate that participants who learned with the novice took significantly less time to answer the Paper 2 than those who learned with the coach ($t(30)$ = -2.074, p = 0.047*) (Table 5.22). After two weeks, of the 16 participants who learned with the novice, 11 (68.75%) took less than 5 minutes to complete the Paper 2, however, of the 16 participants who learned with the coach, only 5 (31.25%) took less than 5 minutes to answer the Paper 2. The shortest session was the same for both groups, 3 minutes and 16 seconds; however, the longest session was different, 6 minutes and five seconds for the NN group and 8 minutes and 42 seconds for the NC group.

Table 5.22: Time to answer Paper 2 (NC vs NN)

	Average	
	NC	NN
Paper 2 answering time	0:05:28	0:04:36

**p <.05*

Accuracy of the Sa'ie definition
After two weeks, the results also show that participants who learned with the coach significantly answered the question of the Sa'ie definition more precise than those who learned with the novice (U = 56, p = .001*) (Table 5.23). These findings are consistent with the outcomes in Section 5.5.3.4 - Accuracy of the Sa'ie definition. Moreover, the number of participants who answered the question correctly two weeks later increased for the NC group, but it decreased for the NN group. Almost all participants who learned with the coach (14/16 - 87.5%) answered the question accurately. However, only 5 of the 16 participants (31.25%) who learned with the novice answered it correctly.

Table 5.23: Sa'ie definition two weeks later (NC vs NN)

	Average	
	NC	NN
Sa'ie definition mark	0.88	0.31

**p <.01; Higher value indicates more mark obtained with the maximum mark of 1*

Sa'ie quiz
The results also demonstrate that participants who learned with the coach significantly obtained more mark than those who learned with the novice (U = 66, p = .014*) (Table 5.24), even after two weeks of the learning session. It also shows that the average mark rose for both NC and NN groups. Of the 16 participants in each group, 10 participants (62.5%) who learned with the coach obtained the maximum mark (9/9) whereas, in the NN group, only 4 participants (25%) gained the maximum mark, also supporting the findings in Section 5.5.3.4 - Sa'ie quiz. Interestingly, these four NN participants were the same participants who obtained the maximum mark after the learning session.

Table 5.24: Quiz mark two weeks later (NC vs NN)

	Average	
	NC	NN
Total mark of Sa'ie quiz	8.25	7

**p <.05; Higher value indicates more mark obtained with the maximum mark of 9*

5.5.4 Comparison of Memory Recall between Short-Term and Long-Term

This section explains the comparison results of knowledge transfer between ST and LT. The examples of results are the accuracy of the Sa'ie definition, answering time between Paper 1 and 2, route recognition and landmarks placement.

5.5.4.1 Accuracy of the Sa'ie definition

Before and after the learning session, participants were asked about the definition of Sa'ie. Both scores were compared and the results exhibit that after learning, participants significantly answered the definition question more accurate than prior to learning ($W = 15$, $p = .008$*) (Table 5.25). Before learning, of all participants (32), only 8 (25%) answered the question correctly. However, after learning, the number of participants who answered it correctly rose sharply, in which 18 of the 32 participants (56.25%) answered it accurately, implying that the learning of Sa'ie procedure had taken place. Surprisingly, of the 8 participants who answered correctly before the learning session, 2 participants did not answer the same question correctly after the learning task.

Table 5.25: Sa'ie definition between pre- and post-session

	Average	
	Pre	**Post**
Sa'ie definition mark	0.25	0.56

**p <.001; Higher value indicates more mark obtained with the maximum mark of 1*

5.5.4.2 Paper 1 and 2 answering time

This section discusses the time difference between answering the Paper 1 and 2 by all participants as well as time difference in answering the Paper 1 and Paper 2 between SG and PPT participants.

All participants

The time to answer all questions between Paper 1 and Paper 2 was compared and the results show that participants significantly took less time to answer the Paper 2 than Paper 1 ($W = 10.5$, $p = .000$*) (Table 5.26). Of the 32, half participants (16/32 - 50%) took less than 5 minutes to answer the Paper 2. However, only 3 (9.38%) took less than 5 minutes to complete the Paper 1. The shortest session in the Paper 1 and 2 was approximately same, that was 3 minutes and 33 seconds, and 3 minutes and 16 seconds respectively. However, the longest session was considerably different, in the Paper 1, it was 13 minutes and 47 seconds, and in the Paper 2, the longest session was 7 minutes and 30 seconds.

Table 5.26: Time to answer questions (ST vs LT)

	Average	
	Paper 1	**Paper 2**
Answering time	0:07:08	0:05:02

**p <.001*

SG vs PPT participants

The time difference in answering the Paper 1 and Paper 2 between learning from the SG and PPT was compared. The results reveal that there was a significant difference (U = 64, p = .016*) (Table 5.27). In particular, the relationship is as follows:

PPT-Paper 2 <SG-Paper 2 <PPT-Paper 1 <SG-Paper 1

PPT participants took the least time to answer the Paper 2. It is followed by SG participants in the Paper 2 and subsequently, PPT participants when answering the Paper 1. However, participants in the SG group took the most time to answer the Paper 1.

Table 5.27: Time difference between Paper 1 and 2 (SG vs PPT)

	Average time	**Difference of time between**
SG-Paper 1	0:07:58	0:02:53
SG-Paper 2	0:05:05	
PPT-Paper 1	0:06:17	0:01:23
PPT-Paper 2	0:05:00	

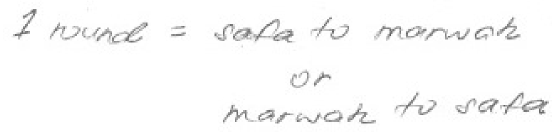
**p <.05*

To complete the Paper 1, the average time taken by participants who learned from the SG was 7 minutes and 58 seconds. In Paper 2, they took on a lower average time of 5 minutes and 5 seconds to complete the same questions as in the Paper 1. For participants who learned from the PPT, the average time to complete the Paper 1 was 6 minutes and 17 seconds. In the Paper 2, they took on average 5 minutes to complete the same questions as in the Paper 1. Although the SG participants took more time than PPT participants to answer the questions of the Paper 1, it seemed that after two weeks of learning, participants took the same time to respond to the questions, regardless of the learning method.

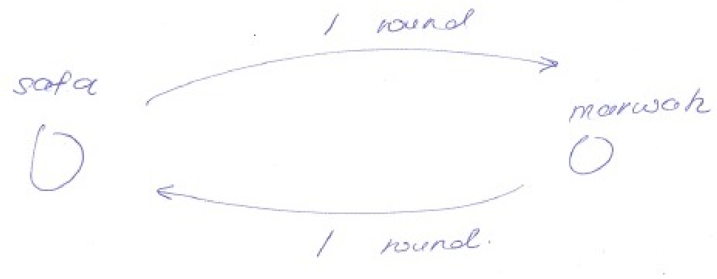
Two weeks later, all 16 participants (100%) who learned from the SG took less time to answer the questions than after the learning session. However, after two weeks, of the 16 participants who learned from the PPT, 12 (75%) took less time to complete the questions than after the learning session; the remaining 3 participants took more time up to 26 seconds, and another 1 participant took the same time as in the Paper 1 (3 minutes and 33 seconds).

5.5.4.3 Post-route recognition

This section describes the comparison results of post-route recognition between Paper 1 and 2 by all participants and also, the difference of post-route recognition in the Paper 1 and 2 between SG and PPT participants.



(a) Paper 1



(b) Paper 2

Figure 5.20: Route recognition by a man

All participants
The comparison results of route recognition between Paper 1 and 2 demonstrate that after two weeks of learning, participants significantly drew the Sa'ie route more accurate than after the learning session ($W = 3$, $p = .034^*$) (Table 5.28). In the Paper 2, 26 of the 32 participants (81.25%) obtained the maximum score (4/4), however, in the Paper 1, the number was a slightly lower, in which 22 of the 32 participants (68.75%) gained the maximum score. The lowest score in the Paper 1 and 2 was same that was 0.29/4. Surprisingly, this score was obtained by the same participant who was a man (Figure 5.20).

	Average	
	Paper 1	**Paper 2**
Total mark of route recognition	3.33	3.65

**p <.05; Higher value indicates more score acquired with the maximum score of 4*

Table 5.28: Route recognition (ST vs LT)

SG vs PPT participants
The difference of post-route recognition in the Paper 1 and 2 between SG and PPT participants was compared and the results show that it was significantly different ($U = 78.5$, $p = .014^*$) (Table 5.29). In particular, there is the following relationship:

PPT-Paper 2 >PPT-Paper 1 >SG-Paper 2 >SG-Paper 1

Participants drew the most precise route after two weeks of learning from the PPT. It is also followed by participants who learned from the PPT but after the learning session and subsequently, participants who learned from the SG after two weeks. However, participants, after learning from the SG, drew the most imprecise route of Sa'ie.

Table 5.29: Post-route recognition difference between Paper 1 and 2 (SG vs PPT)

	Average score	**Difference of post-route recognition between**
SG-Paper 1	2.84	0.7
SG-Paper 2	3.41	
PPT-Paper 1	3.82	0.06
PPT-Paper 2	3.88	

**p <.05; Higher value indicates more score acquired with the maximum score of 4*

The average mark of route recognition after learning from the PPT was 3.82, and it was slightly higher after two weeks of the learning session, which was 3.88. After learning from the SG, participants obtained the average of 2.84 only. However, two weeks later, the average mark increased sharply, from 2.84 to 3.41, with the difference of 0.7. Given that they were asked to do the same task for post-route recognition after the learning session and two weeks later, these findings suggest that participants who learned from the SG recognised the Sa'ie route better two weeks later, although the average score was still lower than those who learned from the PPT.

5.5.4.4 Landmarks placement

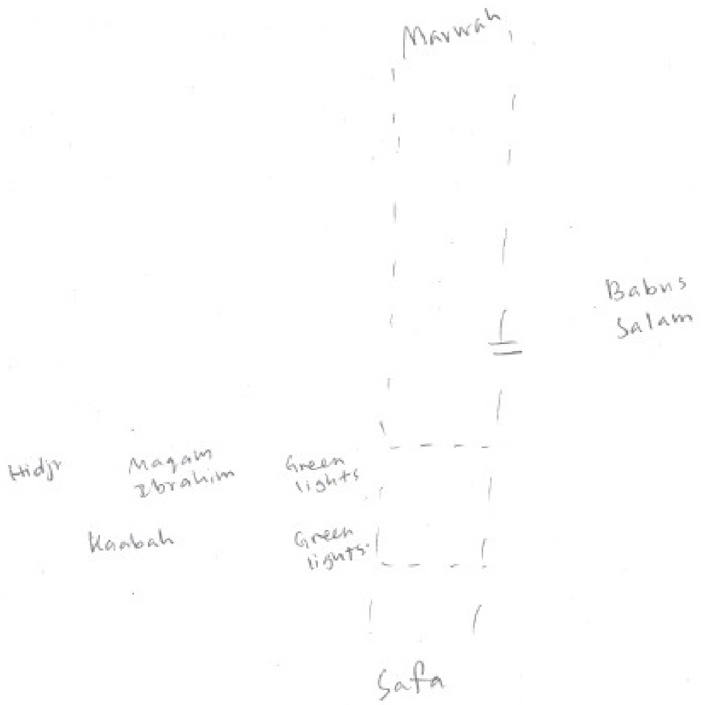
The landmarks placed by participants in the Paper 1 and 2 were compared and the results demonstrate that after two weeks, participants placed the landmarks more accurate than after the learning session ($t(31) = -2.207$, $p = 0.035$*) (Table 5.30). Considering the Paper 2 average as a baseline (1.71/2), 18 of the 32 participants (56.25%) obtained the placement score above the average in the Paper 2, however, in Paper 1 only 10 of the 32 participants (31.25%) gained the placement score above the Paper 2 average. Interestingly, in Paper 1, two participants (6.25%) who were a woman and a man obtained the maximum score (2/2) (Figure 5.21). However, in the Paper 2, they did not gain the maximum score as in the Paper 1 (Figure 5.22).

Table 5.30: Landmarks placement (ST vs LT)

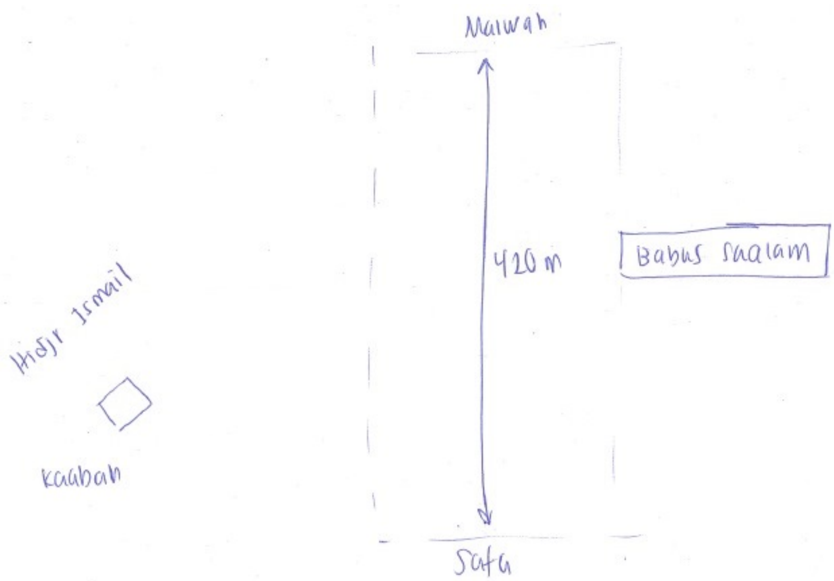
	Average	
	Paper 1	**Paper 2**
Placement score	1.6	1.71

**p <.05; Higher value indicates more score acquired with the maximum score of 2*

The findings in this section and Section 5.5.4.3 - All participants show that after two weeks, participants performed the tasks better than after the learning session; although they took less time to complete it, see Section 5.5.4.2 - All participants.

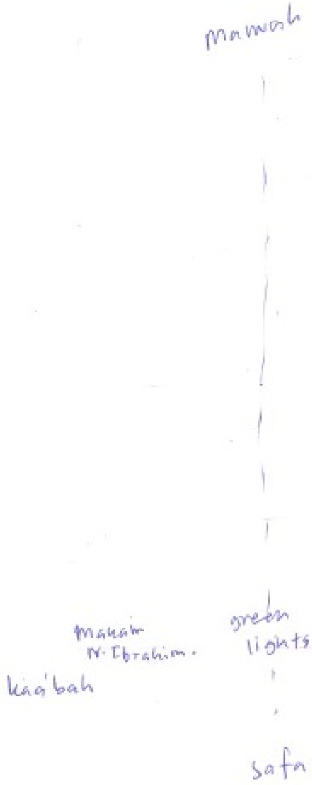


(a) A woman

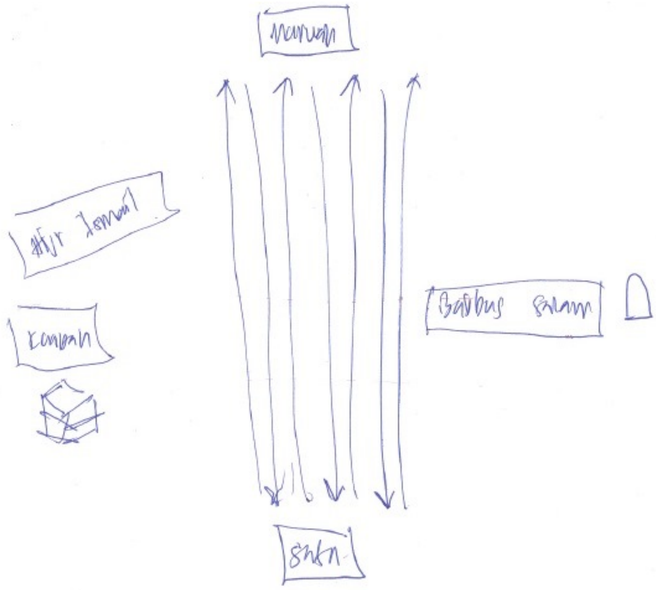


(b) A man

Figure 5.21: Landmarks placement in Paper 1



(a) A woman



(b) A man

Figure 5.22: Landmarks placement in Paper 2

5.5.5 Gender Differences

The following results explain a comparison between genders, considering various elements, such as frequency of playing video games, spatial and navigational abilities, immersive tendency, mood, learning time, collaborative learning and short-term memory recall.

5.5.5.1 Frequency of playing video games

The comparison results of the frequency of playing video games between men and women indicate that men significantly played video games more often than women ($U = 69$, $p = .021^*$) (Table 5.31). Of the 16 men, 4 (25%) played more than five times a week with 2 of them playing every day. However, of the 16 women, only 1 woman (6.25%) played more than five times a week. Regarding whether playing video games or not, 4 men (25%) stated that they did not play, however, for women, half of them (8/16 - 50%) revealed that they did not play video games at all.

Table 5.31: Frequency of playing video games (M vs F)

	Average	
	Males	**Females**
Frequency of playing	3.56	1.88

**p <.05; Higher value indicates higher frequency with the maximum score of 7*

5.5.5.2 Spatial and navigational abilities

The total score of spatial and navigational abilities between males and females was compared, however, no significant difference was found ($t(30) = 1.833$, $p = 0.077$) (Table 5.32). When comparing each item in the abilities test, the results show that men significantly did not confuse right and left much than women ($U = 67.5$, $p = .019^*$) (Table 5.32). Half of the 16 men (8/16 - 50%) strongly agreed that they did not confuse right and left much; however, of the 16 women, only 2 (12.5%) strongly agreed.

Table 5.32: Spatial and navigational abilities test (M vs F)

	Average	
	Males	**Females**
Total score of spatial and navigational abilities	3.75	3.34
Item 1: I do not confuse right and left much	4.13	3.06

**p <.05; Score ranges from 1 - 5, in which 1 = very poor and 5 = very good for total score, and 1 = strongly disagree and 5 = strongly agree for item 1*

5.5.5.3 Immersive tendency

The comparison results of immersive tendency between men and women exhibit that men significantly had a better tendency than women ($t(30) = 2.728$, $p = 0.011^*$) (Table

5.33). Considering the men average as a baseline (3.28/5), half of the men (8/16 - 50%) obtained the total score above the average, however, of the 16, only 3 women (18.75%) gained the total score above the males average.

Items in the test were also analysed. The analysis showed that there was a significant difference between men and women for two items. For example, the results demonstrate that men were significantly involved in a video game that people had problems getting their attention more than women (U = 64.5, p = .014*) (Table 5.33). Of the 16 men, 5 (31.25%) agreed that they were so involved in a video game, however, for women, only 1 out of the 16 (6.25%) agreed that she was so involved. In addition, the results of another item reveal that in the last 48 hours before participating in the experiment, women significantly dwelled on personal problems more than men (U = 74.5, p = .036*) (Table 5.33). Out of the 16, 6 women (37.5%) affirmed that they dwelled much on personal problems. However, of the 16 men, only 2 (12.5%) stated that they dwelled much.

Table 5.33: Immersive tendency test (M vs F)

	Average	
	Males	**Females**
Total score of immersive tendency test	3.28	2.86
Item 1: Do you ever become so involved in a video game that people have problems getting your attention?	2.94	1.88
Item 2: To what extent have you dwelled on personal problems in the last 48 hours?	3.63	2.81

**p <.05; Score ranges from 1 - 5, in which 1 = very poor and 5 = very good for total score, 1 = strongly disagree and 5 = strongly agree for item 1, and 1 = very much and 5 = not at all for item 2*

5.5.5.4 Moods

Mood differences between pre- and post-learning for both genders were compared. The results of pre- and post-overall mood present that Sa'ie learning significantly improved women's mood (W = 0, p = .025*) (Table 5.34). Five of the 16 women (31.25%) reported that they felt more pleasant after the learning session. However, for men, no significant increase was detected (W = 2.5, p = .317), although there was a rise in the post-mood. In the comment section, more than half women expressed that Sa'ie learning was a pleasant and exciting experience.

Sa'ie learning also significantly increased women's happiness (W = 0, p = .008*) (Table 5.35). Of the 16, 7 women (43.75%) felt happier after the learning task. Likewise, men significantly felt happier (W = 0, p = .025*). Five of the 16 men (31.25%) improved their happy score after learning the Sa'ie ritual. Regardless of learning methods or companions, both results indicate that men and women tend to be happier after learning a procedure of ritual.

Table 5.34: Pre- and post-overall mood (M and F)

	Average	
Overall Mood	**Pre**	**Post**
Males	3.19	3.31
Females	3	3.31

**p <.05; Score ranges from 1 - 4, in which 1 = very unpleasant and 4 = very pleasant*

Table 5.35: Pre- and post-happy mood (M and F)

	Average	
Mood: Happy	**Pre**	**Post**
Males	3.19	3.5
Females	3	3.44

**p <.01 or *p <.05; Score ranges from 1 - 4, in which 1 = definitely do not feel and 4 = definitely feel*

Besides, the results of tired mood show that after learning, men significantly felt less tired ($W = 0$, $p = .034$*) (Table 5.36). Five out of the 16 participants (31.25%) decreased the tiredness score after the learning session. However, after learning, no significant difference was found for women's tiredness score ($W = 9$, $p = .157$). Despite the fact that there was a decline in the post-mood, 2 out of the 16 women (12.5%) felt more tired than before the learning session.

Table 5.36: Pre- and post-tired mood (M and F)

	Average	
Mood: Tired	**Pre**	**Post**
Males	2.81	2.44
Females	2.44	2.19

**p <.05; Score ranges from 1 - 4, in which 1 = definitely do not feel and 4 = definitely feel*

No significant difference was found for participants' fed up score before and after learning for both genders.

5.5.5.5 Learning time

The time of learning Sa'ie was compared between males and females and the results indicate that men significantly took less time to learn the Sa'ie ritual than women ($U = 60$, $p = .01$*) (Table 5.37). The shortest learning session for men and women was approximately same, that was 6 minutes and 55 seconds, and 7 minutes and 13 seconds respectively. However, the longest session was considerably different, for men, it was 13 minutes and 10 seconds, and for women, the longest session was 18 minutes and 8 seconds. Of the 16 women, half (8/16 - 50%) took more than 15 minutes to complete the Sa'ie learning whereas all men (100%) took less than 15 minutes.

Table 5.37: Learning time (M vs F)

	Average	
	Males	**Females**
Learning time	0:10:09	0:13:49

**p* <.05*

5.5.5.6 Collaborative learning

The comparison results of enjoyment with the learning companions between genders exhibit that women felt the learning experience was more enjoyable when learning Sa'ie with the companions than men ($U = 68$, $p = .011$*) (Table 5.38). Of the 16 women, 12 (75%) felt very enjoyable to learn Sa'ie with the companions, regardless of whether with the coach or novice. However, for men, only 5 of the 16 (31.25%) stated that they felt very enjoyable. All 16 women (100%) felt very enjoyable or enjoyable, however, of the 16 men, 14 (87.5%) felt very enjoyable or enjoyable, and the remaining 2 (12.5%) stated that they neither felt enjoyable nor bored when learning Sa'ie with their companion. In the comment section, two women reported that the collaborative learning was quite helpful and positively improved their mood to learn Sa'ie.

Table 5.38: Learning enjoyment with the companions (M vs F)

	Average	
	Males	**Females**
Enjoyment score	4.19	4.75

**p <.05; Score ranges from 1 - 5, in which 1 = very boring and 5 = very enjoyable*

These findings may relate to the outcomes in Section 5.5.5.5, in which women spent more time learning because they felt it was enjoyable to learn Sa'ie with their companions despite how much knowledge and experience that their companions had have.

5.5.5.7 Short-term memory recall

In this section, the results of memory recall that was administered after the learning task are presented, in particular, landmarks recall.

Landmarks recall

The total of landmarks recall between men and women was compared. The results show that after learning the Sa'ie ritual, women significantly recalled more landmarks than men ($U = 70.5$, $p = .023$*) (Table 5.39). The maximum number of landmarks recalled by men was seven, however, for women, it was slightly higher, that was nine landmarks. Of the 16 men, only 5 (31.25%) recalled more than five landmarks. However, half of the women (8/16 - 50%) recalled above five.

With regards to the results in Section 5.5.5.5, as women spent more time learning, they,

Table 5.39: Landmarks recalled after learning (M vs F)

	Average	
	Males	**Females**
Total of landmarks recalled	5	6

**p <.05; Higher value indicates more landmarks were recalled*

therefore, tend to recall more landmarks from the environments, whether from the SG or PPT.

5.5.6 Observations

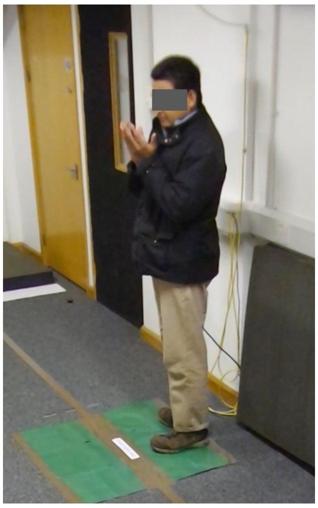
In this section, the observations of participants' behaviour are presented, both during the learning task and in the tasks after it. For instance, conversation and note taking while learning, learning video and audio of participants who used the SG to learn Sa'ie, justification of answers selected in the Sa'ie quiz, the performance of the physical task and finally, participants' drawings in the landmarks placement and route recognition task.

5.5.6.1 Conversation during learning

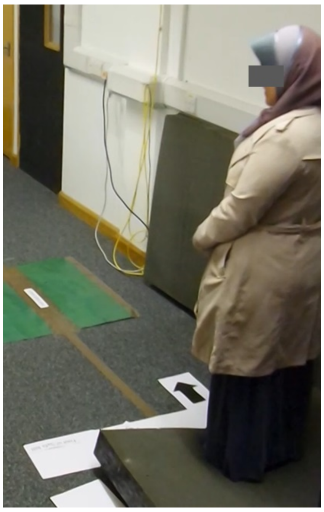
In addition to counting the total questions asked by participants, the participants' conversation was also analysed to examine their behaviour. The analysis revealed that of the 8 participants who learned from the SG and with the novice (SG and NN group), 4 (50%) did not ask a question on Sa'ie at all during the learning session. The results of the Sa'ie quiz moreover show that 3 of them obtained the mark below the overall average (the overall average considering all participants was 7.47). The participant who obtained the quiz mark above the overall average, however, indicated that he felt less tired after the learning session.

The conversation analysis also showed that participants who learned with the novice (NN group) asked questions only on what had been written on the method, whether learning from the SG or PPT. However, those who learned with the coach (NC group) asked questions which were not written, indicating that they tend to seek more detailed explanations from the coach. According to the analysis, participants in the NC group asked this question (not written), at least four questions during the learning session. In the comment section, a few NC participants reported that learning with the coach helped them to understand the process of doing Sa'ie correctly.

Although the comparison analysis of questions asked between males and females did not detect any significant difference, the conversation analysis showed that women asked more questions than men, up to 38 questions during the learning session. For men, the maximum number of questions was only 13. However, the women (2 women) who asked the highest number took 18 minutes and 3 seconds to complete the Sa'ie learning whereas the men (2 men) took 13 minutes and 10 seconds only. The similarity of these participants (2 women and 2 men) was they learned Sa'ie with the coach. Furthermore, the results of the Sa'ie quiz indicate that regardless of genders, they gained the quiz mark above the overall average, with 2 of them (2/4) gained the maximum mark (9/9).



(a) A man



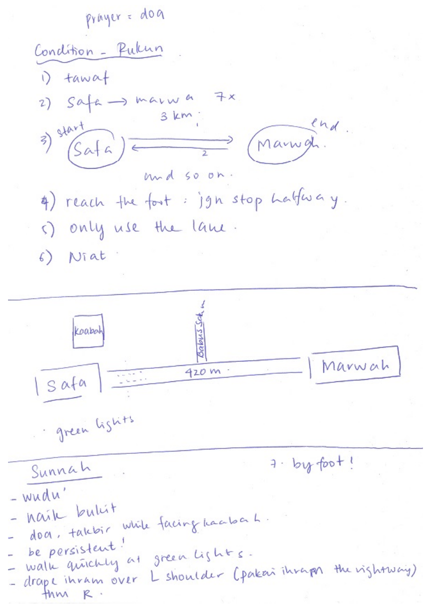
(b) A woman

Figure 5.23: Misunderstandings proved in the physical task

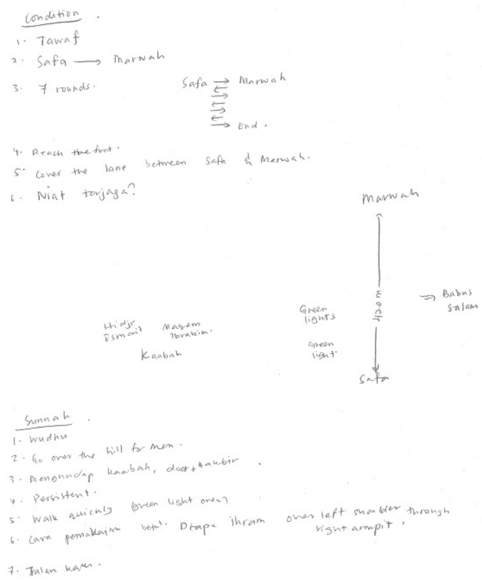
The analysis moreover revealed that all participants (8/8 - 100%) who learned from the PPT and with the novice (PPT and NN group) developed misunderstandings while learning. Surprisingly, 2 out of the 8 participants, who were a man and a woman, proved their misunderstanding in the physical task. For example, when his companion (novice) asked about an exact place to make a prayer, the man answered that pilgrims did not make a prayer at Safa or Marwah hill, but performed it by taking some time to face Kaabah while walking, although the exact places are at both hills. In his physical task video, he showed that he made a prayer at the green lights area, not at the hills (Figure 5.23a). He was 1 of the 4 participants who behaved like this in the physical task, see Section 5.5.6.5. For the woman, when her companion (novice) asked about seven rounds of Sa'ie, she answered that since Sa'ie had seven rounds and Sa'ie began from Safa hill, therefore pilgrims would finish it at Safa hill, although pilgrims actually must end it at Marwah hill. In her physical task video, she ended the task at Safa hill (Figure 5.23b) and in fact, she completed six rounds only, instead of seven rounds. In the comment section, most of the participants in this group (PPT and NN group) reported that Sa'ie information in the PPT was not so clear and difficult to remember which restricted the performance of the physical task. They also said they could not imagine the real situation. These findings, therefore, suggest that collaborative learning without the coach did not help learners, in particular, beginners, to understand the learning content correctly.

5.5.6.2 Note taking while learning

Participants were given blank A4 papers if they needed it to write something during the learning session. All these papers were collected and analysed. Of the 16 participants who learned from the SG, almost all (14/16 - 87.5%) did not use the paper while learning. Whereas for the PPT participants, all of them (16/16 - 100%) took note while learning. Based on the papers used by 18 participants (2 SG and 16 PPT participants), 12 drew the rounds of Sa'ie to indicate how to count it, 12 wrote about Conditions and Options, and 8 drew the location of landmarks (Figure 5.24).

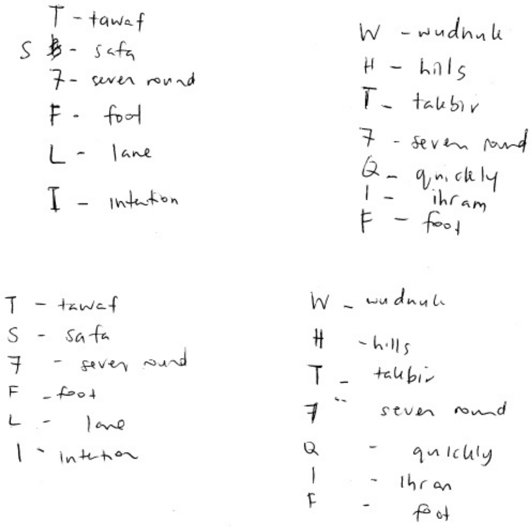


(a)



(b)

Figure 5.24: Note taking while learning



(a)

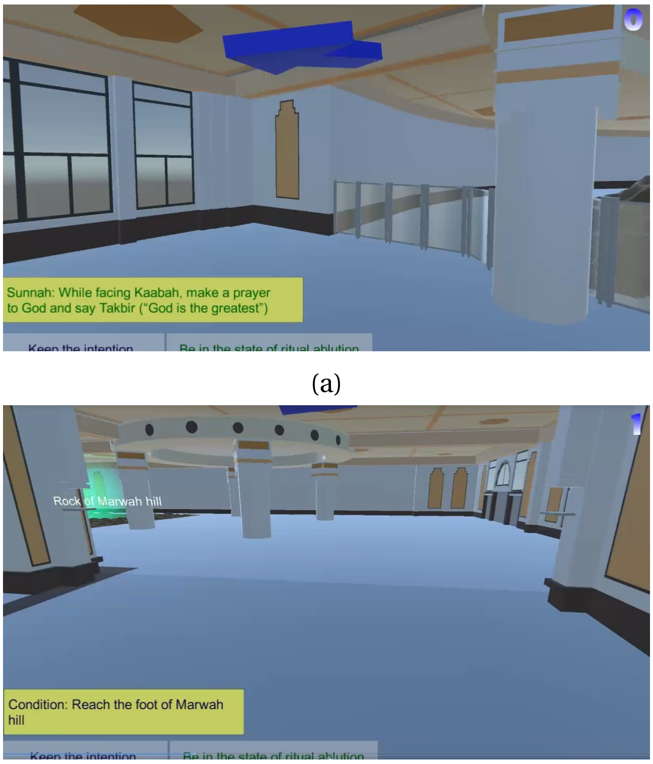
(b)

Figure 5.25: Initialism concept used to write note

Interestingly, of the 12 who wrote about Conditions and Options, 2 participants (16.67%) who were women used the initialism concept to learn and memorise the knowledge (Figure 5.25).

5.5.6.3 Serious game learning video and audio

Sixteen participants were assigned to learn from the SG, with eight (50%) learned with the coach and the other eight (50%) learned with the novice. Their learning session while using the SG was video recorded and analysed. The video analysis exhibited that all participants (8/8 - 100%) who learned with the novice stopped their navigation at least five times to read the information on the screen (Figure 5.26). They stopped to read it in the first round and at the beginning of the second round. They afterwards did not stop any more until they completed all seven rounds.



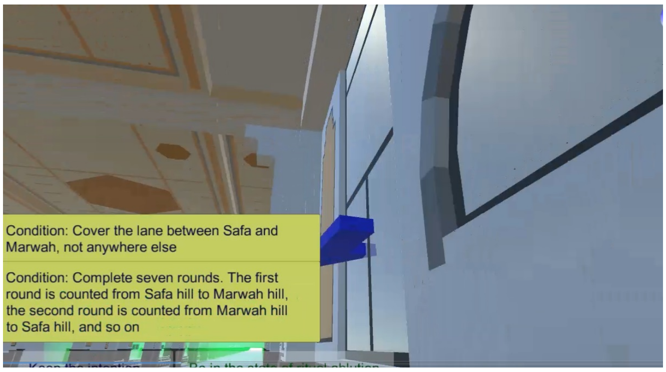
(a)

(b)

Figure 5.26: Places where novices stopped while learning

Interestingly, of the 16, 6 participants (37.5%) started their learning with the discussion in the first place, but they had been silent until the end. All of them, however, learned Sa'ie with the novice. Also, the video analysis showed that they had been silent from the second round and onwards. Their result of the Sa'ie quiz was checked, and it shows that 5 of them got the mark below the overall average (the overall average considering all participants was 7.47). However, of these 6, 3 participants reported in the comment section that the experiment was interesting.

Surprisingly, of the 16 SG participants, 2 (12.5%) only did not hit the wall while navigating in the game environment. Their background information revealed that they played video games every day, validating that their performance was better than the others. Also, 1 of these 2 commented that it was very fun to learn the Sa'ie ritual using the game. Of the 14 who hit the wall, 2 participants (14.29%) hit 27 times (Figure 5.27). The conversation analysis was checked, and these 2 participants admitted that they never played video games before. Their declaration was also in line with the background information they entered previously, stating that they did not play video games.



(a)

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Figure 5.27: Participants hit the walls while playing the game

Furthermore, the video analysis demonstrated that half of the participants (8/16 - 50%) faced difficulties to control the navigation, both for movement and camera orientation, which might distract their attention to learn the Sa'ie ritual. However, 6 of them (75%) showed that they felt harder to control it. For example, while learning, they moved in the environment with the blue arrow facing them, although the arrow supposedly pointed forward to show them a direction to follow (Figure 5.28a). Also, in the beginning, 2 of these 6 participants kept moving about 1 minute and 7 seconds, in the area close to Safa hill looking for the next point to go (Figure 5.28b). The information of playing video games was checked, and it shows that all 6 participants played video games less often or did not play at all. Also, the quiz result of these eight participants was reviewed, and it shows that 6 of them got the mark below the overall average. In the comment section, 2 of them suggested that it might be easier to control the movement in the SG by using a joystick.

The findings of hitting the wall and encountering difficulties while navigating in the SG are similar with the results of Study 1 (see Section 4.5.3.3). In the former study, three participants cut through buildings while moving in the environment which demonstrated that they faced difficulties in using the keyboard keys to navigate.

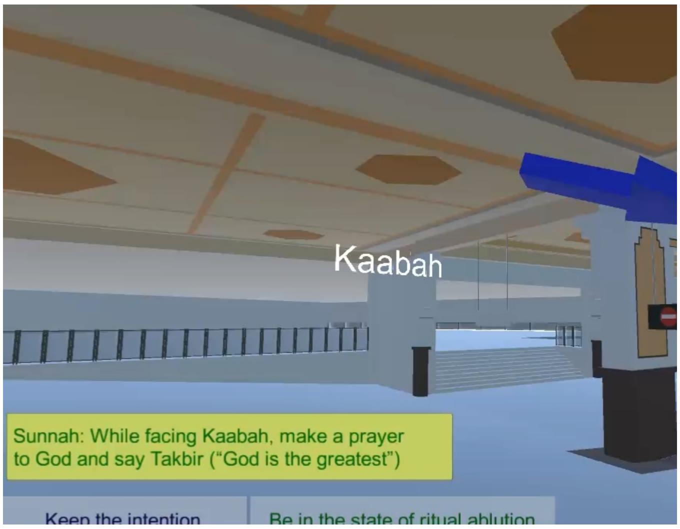
(a) Arrow facing players

(b) Kept moving at Safa hill for a while

Figure 5.28: Difficulties in controlling the game

The 2 participants, who hit the wall 27 times, were 2 of the 6 participants who felt harder to play the SG. The further analysis indicated that they moved the blue arrow out of building four times, displaying that they felt difficult to use the arrow keys to control the arrow (see Figure 5.27). The video analysis moreover showed that the difficulties of controlling the game continued until the end of the sixth round. Their voice recording was also analysed, and it revealed that they did not see the round counter in the first place, indicating that they fully focused on how to control the navigation.

Although some participants encountered difficulties to play the SG, the video analysis demonstrated that all participants (16/16 - 100%) learned about spatial knowledge from the game. During the learning session, they kept moving the camera to find landmarks. For example, they tried to find Kaabah by looking around when they were at Safa hill or Marwah hill (Figure 5.29). The video recording indicates that they also said Kaabah must be on the left when they were at Safa hill and on the right when they were at Marwah hill.



(a)

(b)

Figure 5.29: Spatial learning while playing the game

5.5.6.4 Justification of answers in the Sa'ie quiz

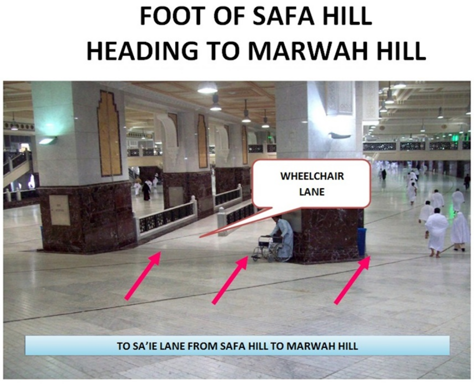
There were 11 questions in the Sa'ie quiz that was administered after the learning session (Paper 1). Of these 11, 2 were extended questions which asked participants to justify their previous answer. To justify the answer of Question 1: 'Where is the start of Sa'ie?', the majority participants (28/32 - 87.5%) clarified that they learned it from the previous learning session, whether from the SG or PPT, or with the coach or novice. Another three participants (9.38%) stated that they noticed the signpost of 'Safa Start' at Safa hill. The most surprising results to emerge from the data are that all of them learned Sa'ie from the PPT; indicating that they noted the signpost just in the picture (Figure 5.30). However, the results of landmarks recall, show that after the learning session, they recalled landmarks below the overall average (the overall average considering all participants was 5.5). The remaining one participant (3.13%), who was a woman, unfortunately, did not defend her answer, although she responded to the question correctly.

Figure 5.30: The signpost of ‘Safa Start’ in the PPT

For Question 2: ‘Can pilgrims perform Sa’ie by riding (not by foot)?’, of the 32 participants, 19 (59.38%) indicated that they learned it from the previous learning session, whether from the SG or PPT, or with the coach or novice. Another six participants (18.75%) justified that the answer was based on their common sense and the other five (15.63%) noticed the wheelchair lane during the learning session (Figure 5.31). Of these 5 (a group that saw the wheelchair lane), 4 participants learned it from the SG, and another participant learned it from the PPT. Interestingly, after the learning session, these four SG participants recalled landmarks above the overall average, with a woman who recalled the highest number of landmarks (nine landmarks) (see Figure 5.19a). Two of them also commented that they visually remembered the main physical elements from the game environment. However, the PPT participant recalled the landmarks below the overall average. Surprisingly, another participant (3.13%) who was a woman stated that she was unsure of her answer. Her reason, however, was acceptable because she responded to the question wrongly. The remaining one participant (3.13%) did not justify her answer. She was also the same participant who did not defend her answer for Question 1. However, for this question, she answered wrongly.

Both women who stated they was unsure of their answer (woman 1) or did not defend their answer (woman 2), learned Sa’ie from the SG. For woman 1, her overall mood was still very unpleasant even after learning. Also, she revealed that she dwelled on personal problems very much in the last 48 hours before the experiment began. The results of the Sa’ie quiz also show that she obtained the mark below the overall average (6/9; the overall average considering all participants was 7.47). These findings suggest that an unpleasant mood may negatively influence a learning process. On the other hand, woman 2 felt less tired and fed up after the learning session. However, the results of the Sa’ie quiz indicate that she obtained the mark below the overall average (5/9). Besides, before the learning session, she neither agreed nor disagreed that she was alert at present. These findings may support her behaviour to disregard the justification to both questions.

(a) In SG

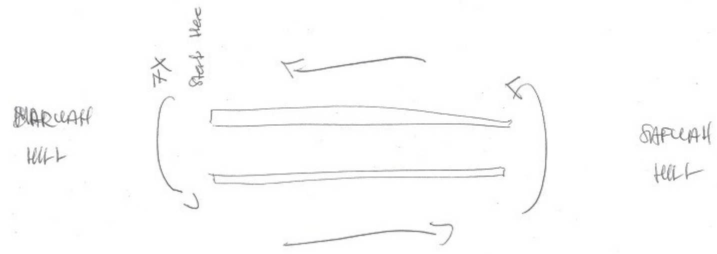


(b) In PPT

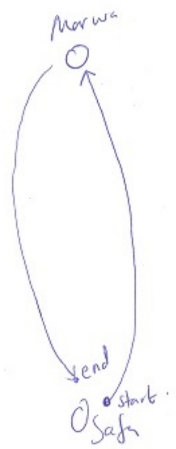
Figure 5.31: The wheelchair lane

5.5.6.5 Physical task

The performance of the physical task was scored and the average considering all participants was 12.56. Of the 32 participants, 3 (9.38%) obtained the score above 16 and another 3 participants (9.38%) obtained below 10. Surprisingly, the similarity of all these six participants was they learned from the SG. However, all participants that gained above 16, who were 2 women (women A and B) and 1 man, learned Sa'ie from the coach. According to results from other tasks in the Paper 1, they also performed very well, for example, women A recalled the highest number of landmarks (nine landmarks) (see Figure 5.19a), women B obtained the maximum mark for Sa'ie quiz (9/9) and the man recalled seven landmarks and also obtained 8 out of 9 for the quiz. In the comment section, they reported that they learned a lot from the SG and coach, and the SG was fascinating. For 3 participants who gained the physical task score below 10, the results from other tasks demonstrate that their quiz mark and route recognition score (Figure 5.32) were lower than average. One of them, who was a man, was 1 of the 3 participants who gained the lowest mark for Sa'ie quiz (4/9). Also, he was the same participant who hit the wall 27 times while learning from the SG, see Section 5.5.6.3.



(a)



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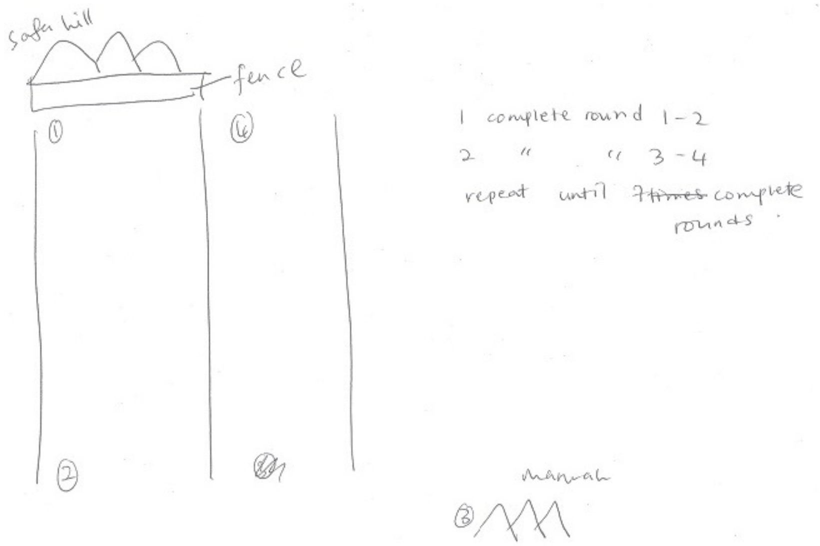


(c)

Figure 5.32: Route recognition by three participants

The physical task video of the 32 participants was examined to understand the participants' behaviour in detail. The analysis showed that of the 32 participants, 13 (40.63%)

Figure 5.33: Used fingers while counting the rounds of Sa'ie

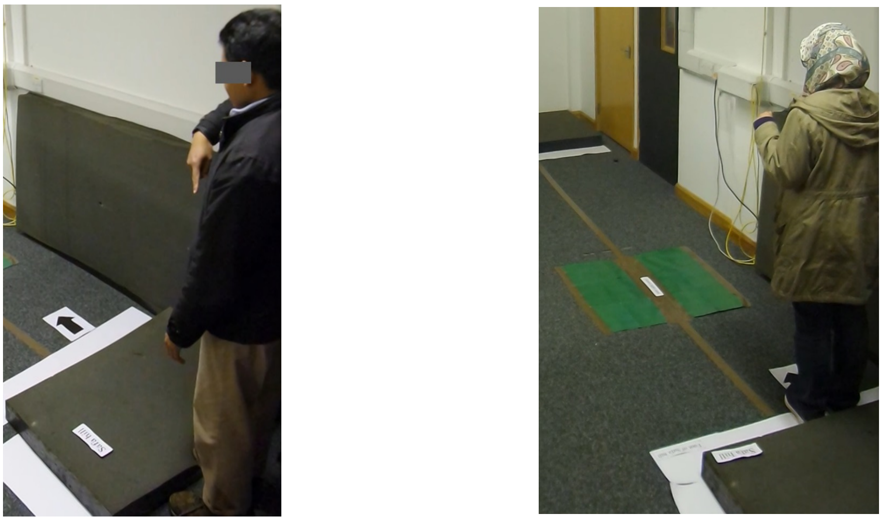


Figure 5.34: Participants stopped to count the rounds

counted the rounds of Sa'ie loudly. Of these participants, 8 counted loudly for each round from the first to the seventh round, and the rest counted loudly for some rounds. Besides, of the 8 participants who counted loudly for each round, 3 participants used their fingers to remember the number of rounds they were walking on (Figure 5.33). While performing the physical task, of the 32, 12 participants (37.5%) lost count of the rounds with 10 of them stopping and taking some time to recount the rounds (Figure 5.34), although, in the comment section, 1 of these 12 participants reported that the indoor area was small. Also, the video analysis indicated that 2 participants (6.25%) counted the rounds of Sa'ie wrongly, in which they counted one round from Safa to Marwah and back to Safa, while the actual count for one round was just from Safa to Marwah and the next round was from Marwah to Safa and so on. Surprisingly, both of them learned Sa'ie from the SG; however, they learned it with the novice. Their results of route recognition task validate this behaviour as they obtained a score lower than average (1/4 and 2/4; the overall average considering all participants was 3.33) (see Figure 5.32a - 5.32b).

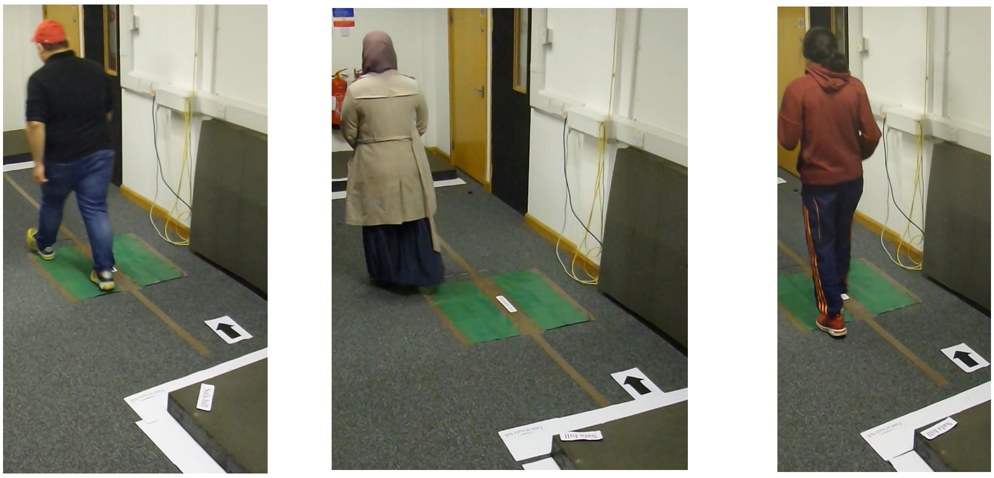


Figure 5.35: Walking on the wrong lane

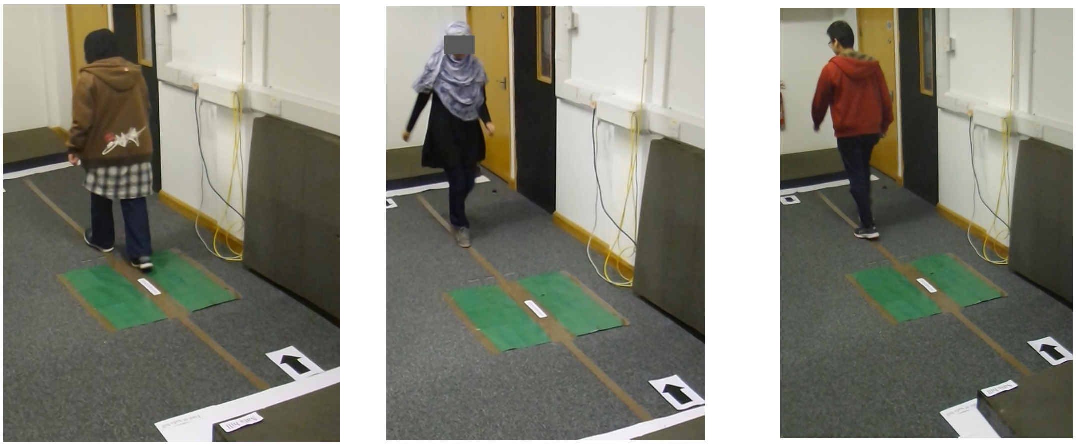


Figure 5.36: Walking in the middle area

The way that they walked in the indoor area while performing the route and ritual actions was also studied. In the indoor area, the walking lane was divided into two that was a lane from Safa to Marwah, and vice versa. Both walking lanes had an arrow to show the direction to the participants. However, the video analysis presented that three participants (9.38%) walked into the wrong lane (i.e. to go to Marwah hill, they supposedly used a lane from Safa hill to Marwah hill, but they used a lane from Marwah hill to Safa hill or the other way round) (Figure 5.35). The analysis furthermore indicated that they obviously did not refer to the arrow while walking between two hills. Of these 3, 2 participants walked on the wrong lane all rounds until they completed the physical task and the other one walked on the wrong lane during the first and third round. The data also shows that these three participants learned Sa'ie from the PPT. One of them, in the comment section, reported that the PPT was useful however it reduced his performance level in the physical task. Besides, of the 32, 8 participants (25%) walked in the middle area that was on a line tape used to divide the two walking lanes. Of these

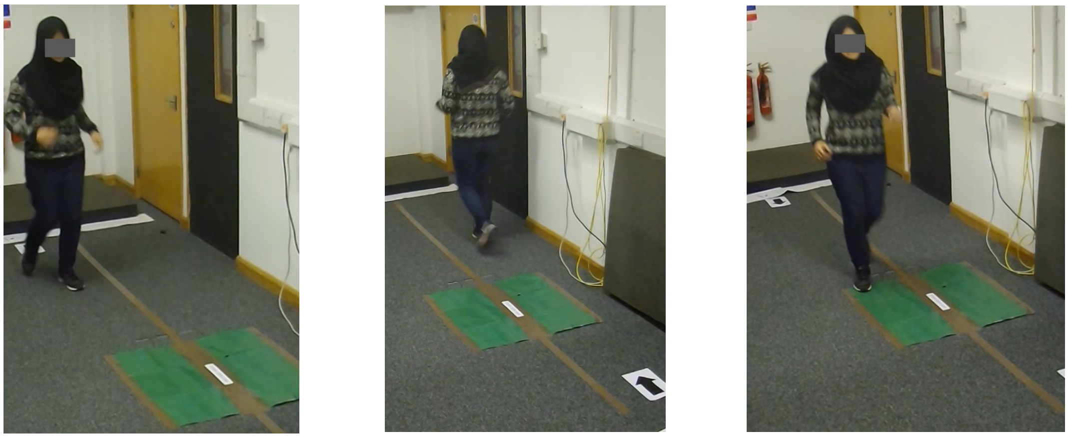


Figure 5.37: A woman who kept running in the physical task

participants, 5 walked in this area most of the time while performing the physical task (Figure 5.36) and another 3 participants walked there for the first round only. The most surprising behaviour from the video analysis was that there was a woman (3.13%) who ran all the time while doing the task (Figure 5.37). She was also one of the participants who counted the rounds of Sa'ie loudly for some rounds. Her overall mood was checked, and the results disclose that she felt very unpleasant for both times, whether pre- and post-learning.

Figure 5.38: Participants made a prayer at the green lights area

Also, of the 32, 4 participants (12.5%) who were all men made a prayer at the green lights area, although they supposedly performed it at Safa hill and Marwah hill (Figure 5.38, see also Figure 5.23a). Another participant (3.13%) who was a man, in the video, mentioned that he was unsure what to say at Safa hill and Marwah hill. Previously, he learned Sa'ie from the SG; however, he learned it with the novice.

The behaviours of the 3 participants who obtained the score above 16 and another 3 who obtained below 10 were also observed. The video analysis showed that all 3 participants who gained above 16, who were 2 women (women A and B) and 1 man, counted

Figure 5.39: Women A and B who obtained a high score

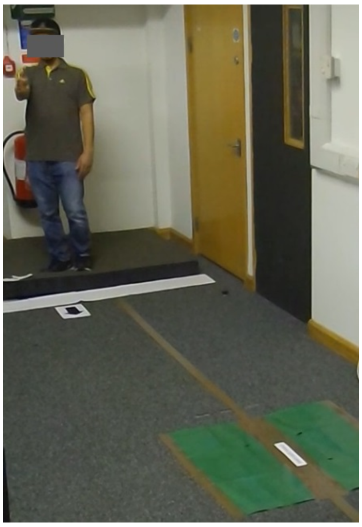


Figure 5.40: A man who obtained a high score

loudly for each round while performing the physical task. Also, they explained at least three Conditions or Options before performing the Sa'ie ritual. Amongst these 3 participants, women A obtained the highest score for the physical task, and it is followed by woman B and the man. Their performance video reveals that those 2 women gained higher score than the man because they performed more Options than him (Figure 5.39). However, his physical task performance was excellent because he described the actions more thorough than the 2 women as if he was a coach (Figure 5.40). For instance, he stated that pilgrims were required to be in the right lanes and Kaabah was located at the right-hand side while pilgrims were at Marwah hill. For 3 participants who obtained below 10, the video analysis revealed that 2 of them were the same participants who counted the rounds of Sa'ie wrongly. The remaining 1 participant was the woman who kept running all the time while performing the physical task.

5.5.6.6 Drawings

Participants' drawings in the landmarks placement and route recognition task were also observed. Although 16 participants learned from the same method (16 learned from the SG and another 16 learned from the PPT), interestingly, some of them did the different drawing. Even they were asked to do the same tasks in the Paper 2; some of them also did the different drawings as compared to the drawings in the Paper 1. The following sections discuss the drawing observation in detail.

Landmarks placement

In the landmarks placement task, participants were asked to place the landmarks they could recall on the paper. According to the observation, participants produced five different drawings. In any drawing, Kaabah was drawn on the left side where was close to Safa hill. However, participants positioned the two hills in different locations on the paper. Table 5.40 briefly describes the drawings (see Appendix D for full description).

Table 5.40: Drawings in landmark placement task

On the paper			Number of participants	
Drawing no.	**Location of Safa hill**	**Location of Marwah hill**	**Paper 1**	**Paper 2**
1	Bottom	Top	13	11
2	Right	Left	6	4
3	Left	Right	11	16
4	Southwest	Northeast	1	1
5	Top	Bottom	1	–

In the Paper 2, of the 32 participants, 23 (71.88%) produced the same drawing of landmarks placement as in the Paper 1. However, the remaining 9 (28.13%) did not perform the same drawing in Paper 2. Moreover, the overall findings indicate that participants exactly positioned the hill of Safa and Marwah at the same locations as they learned from the PPT, using the bottom and the top of the paper as locations. However, when participants learned from the SG, they tend to locate the hills on the left or the right of the paper, although they moved forward in the game environment most of the time.

Route recognition

In the route recognition task, participants were asked to acknowledge that they had to walk through the route seven times by drawing and numbering the rounds from Safa hill to Marwah hill on the paper. In the Paper 1, there were 14 drawings produced by participants. However, the number increased to 20 drawings in the Paper 2, in which 11 drawings were similar as in the Paper 1. Of the 32 participants, in the Paper 1, 30 drew the route, and another 2 described the route in text only. In the Paper 2, all 32 participants drew the route with one participant also included an extended text description of his drawing.

The drawings are briefly described in Table 5.41, 5.42 and 5.43 (see Appendix E for full description). Table 5.41 explains the 11 same drawings in the Paper 1 and 2.

Table 5.41: Eleven drawings in the Paper 1 and 2

On the paper						Number of participants	
Drawing no.	**Location of Safa hill**	**Location of Marwah hill**	**Number of lines**	**Line pattern**	**Numbering pattern**	**Paper 1**	**Paper 2**
1	Bottom	Top	7	Straight	Left to right	6	2
2	Left	Right	7	Straight	Top to bottom	6	4
3	Left	Right	7	Straight	Middle to top/bottom, but not continuous	1	1
4	Left	Right	7	Straight	Top to bottom, but not continuous	1	1
5	Left	Right	7	Straight	Bottom to top	1	1
6	Left	Right	2	Straight	Left to right, but not continuous	3	2
7	Right	Left	2	Straight	Left to right, but not continuous	3	2
8	Southwest	Northeast	2	Curved	No number	2	2
9	Left	Right	7	Curved	Middle to top/bottom, but not continuous	1	2
10	Bottom	Top	7	Curved	Middle to right/left, but not continuous	2	1
11	Left	Right	1	Continuous curved	Top to bottom	1	1

Table 5.42 describes 3 additional drawings in the Paper 1.

Table 5.42: Three drawings in the Paper 1

On the paper						Number of participants
Drawing no.	**Location of Safa hill**	**Location of Marwah hill**	**Number of lines**	**Line pattern**	**Numbering pattern**	
12	Top	Bottom	7	Straight, but from northeast to southwest	Right to left	1
13	Southwest	Northeast	7	Straight, but from southwest to northeast	Left to right	1
14	Left	Right	7	Curved	Right/left to middle, but not continuous	1

Table 5.43 describes 9 new drawings in the Paper 2.

Table 5.43: Three drawings in the Paper 1

On the paper						Number of participants
Drawing no.	**Location of Safa hill**	**Location of Marwah hill**	**Number of lines**	**Line pattern**	**Numbering pattern**	
15	Left	Right	7	Straight	Top to bottom (untidy position)	1
16	Left (Label 4 times)	Right (Label 4 times)	7	Straight, but from northwest to southeast	Top to bottom	1
17	Left	Right	7	Straight, but from northwest to southeast	Top to bottom	1
18	Bottom	Top	7	Curved and straight	Left to right	1
19	Left	Right	7	Curved	Middle to bot-tom/top, but not continuous	3
20	Bottom	Top	7	Curved	Middle to left/right, but not continuous	2
21	Bottom	Top	2	Straight	Top to bottom, but not continuous	2
22	Right	Left	2	Straight	Middle to bot-tom/top, but not continuous	1
23	Left	Right	2	Straight	Middle to right/left, but not continuous	1

In the Paper 2, less than half of the participants (14/32 - 43.75%) produced the same drawing of route recognition as in the Paper 1. However, another 18 participants (56.25%) did not perform the same drawing in the Paper 2. Furthermore, the overall findings demonstrate that participants who learned from the PPT, numbered the rounds of Sa'ie continuously, regardless of the starting location of the round, whether from left to right or from top to bottom of the paper. For the SG participants, the findings are similar to the findings in Section 5.5.6.6 - Landmarks placement in which they tend to position the hills whether on the left or the right when drawing it back on the paper.

5.6 Discussion

The main findings of the experiment are summarised below.

Learning experience and moods
Participants who learned from the PowerPoint note were more accurate on the Sa'ie definition, obtained higher mark in the quiz and recognised the Sa'ie route more precise than participants who learned from the serious game, although the latter felt that they had a better memory for where they left things than the former. As the Sa'ie game did not have much gamification as video games always have, it is speculated that this was one of the reasons why learning from the serious game did not help learners to grasp the factual knowledge better. However, participants who learned from the serious game recalled more landmarks from the environment, even two weeks later. The audio and video recordings indicate that these participants learned about spatial knowledge while navigating in the virtual environment. The findings are in line with the opinions of Ruddle et al. [74] that repeated navigation in virtual environments improves users' spatial knowledge and memory.

When participants were asked to locate the hills on paper, participants who learned from the PowerPoint note positioned the hills using the bottom and the top of the paper, the same locations they learned from the note. However, participants who learned from the serious game located the hills on the left or the right of the paper, although they moved forward in the virtual environment.

Apart from that, according to users' self-reported score, the serious game was more interesting, more helpful and had a higher sense of presence than the PowerPoint note. With regards to participants' overall mood, they felt more pleasant after learning from the serious game. However, regardless of learning methods, all participants felt happier after learning the ritual.

The findings of navigation in the serious game recalled landmarks, it was interesting, and an increase in users' moods after playing the serious game supports the similar outcomes in Study 1.

Collaboration and moods
After learning from the coach, participants performed the physical task better than participants who learned with the novice. They also were more accurate on the Sa'ie definition and obtained higher mark in the quiz, even two weeks later. The audio and video recordings show that they asked more (and further) questions than participants who learned with the novice.

In connection with participants' overall mood, they felt more pleasant after learning the ritual with the coach. However, regardless of companion's knowledge, all participants felt happier after learning the ritual. Participants who learned with the novice, moreover, felt less tired after the learning session.

With regards to learning with the novice only, all participants developed misunderstandings when learning from the PowerPoint note. When learning from the serious game, all participants stopped the navigation several times, and some of them did not ask questions and liked to be silent until the end of the learning session. Regardless of learning methods, some participants performed wrong actions in the physical task.

Knowledge transfer
All participants performed well in the post-session tasks, in particular, participants who learned from the PowerPoint note were able to recognise the route and did well in the quiz, and participants who learned from the serious game were able to recall landmarks. Also, before learning, although one-fourth only knew the definition of Sa'ie precisely, participants were more precise after the learning session. The findings indicate that the ritual knowledge was transferred from learning methods according to the learning objectives, but again as in Study 1, the level of retention was individually different.

After two weeks, participants were more accurate on route recognition and landmarks placement than after the learning session; although they took less time to finish the tasks as compared to the time taken after learning, demonstrating that in general knowledge and experience that gained previously remain in their memory.

Gender differences and moods
Considering gender abilities, men had a better immersive tendency, and also, they did not confuse right and left as much as women. Regarding the frequency of playing video games, men played more often, and they were so involved in games that people had problems getting their attention. In connection with personal life, women dwelled more on personal problems in the last 48 hours before participating in the experiment. However, women felt more enjoyable learning Sa'ie with their companion regardless of the level of knowledge their companion had, and they also recalled more landmarks than men. The findings are in line with what Stump et al. [186] and Chan et al. [187] found, when involving the collaboration, women fully utilised it and were more active than men. According to task completion time, men took less time to learn the ritual than women.

With regards to overall mood, women felt more pleasant after learning the ritual. However, regardless of genders, all participants felt happier after learning the ritual. Men, however, felt less tired after the learning session.

5.7 Conclusion

The purposes of this study were to examine the efficiency of a serious game to learn a set of ritual procedure as compared to PowerPoint note, to check the need of a coach to enhance learning performance, to investigate the efficacy of learners' memory in a short and long-term period and to find gender differences while learning a ritual. The study presented here suggests that serious game might be a better method of learning a ritual from the users' self-reported score and knowledge transfer of landmarks representations than PowerPoint note. However, PowerPoint note is still a valid instrument in ritual learning to understand and remember factual knowledge. Besides, the study advocates that learning with a coach is a better collaboration than learning with a novice as the sufficient knowledge is delivered correctly. The study also indicates that the previous experience remains in users' memory although two weeks later, and women utilise the collaboration and enjoy learning than men despite their weaknesses and personal problems.

Therefore, it is concluded that serious game is a better learning method if the purpose of a digital experience is to enhance long-term knowledge transfer on landmarks representations and have pleasurable experience overall. It is also concluded that PowerPoint note can be used to learn factual knowledge. Finally, it is concluded that learning with a coach improves the knowledge and experience of novices, and women enjoy learning with a companion.

5.8 End-of-chapter Summary

To summarise, serious games are an acceptable medium for ritual learning, in particular when it involves memorising the landmarks from the virtual environment for a long-term period. Having a coach to learning experience is undoubted due to precise and adequate knowledge delivery. Apart from that, women enjoy collaborative learning.

Chapter 6

Findings of Study 1 and 2

Contents

The findings on mood and learning in the navigation-based virtual environment and serious game were reported in this chapter. It was also published in the Journal of Computer in Human Behavior (Elsevier) [244], with DOI: 10.1016/j.chb.2017.03.040.

6.1 Introduction

This chapter presents some results of the participants who learned from the virtual environment (Study 1[1]) or serious game (Study 2) only. Therefore, the results of 36 participants in Study 1 and 16 participants in Study 2 were taken. In Section 6.5, the results of these participants (36 + 16 = 52 participants) were combined to find any relationship with learning performance.

[1] In this chapter, Study 1 is called Experiment 1, and Study 2 is called Experiment 2.

6.2 Data Collection Method

6.2.1 Questionnaire

The questionnaire were same as in Section 4.3.3, Chapter 4 and Section 5.3.3, Chapter 5.

6.2.2 Learning Performance

The learning performance of the participants was measured as follows:

6.2.2.1 Criterion 1: Navigate route in the real world

In Exp.1, the volunteers' route was tracked with a popular mobile app commonly used for tracking fitness activities (RunKeeper, https://runkeeper.com/). A score of one was given if they reached the destination by following the exact same route, a score of 0.5 was given if they took a wrong path although they still reached the destination, and a score of zero was given if they did not reach the destination at all.

In Exp.2, a small indoor area to resemble the reference points in Mas'a was prepared, and after receiving consents, the participants' navigation during the ritual was video recorded. Their navigation score was given based on whether they chose the correct starting (1 point) and end point for the ritual (1 point), and that they completed the route by performing all the seven rounds as prescribed (1 point maximum, 0.14 per each round). The maximum score for criterion 1 in Exp. 2 was three.

6.2.2.2 Criterion 2: Draw route and recall landmarks

In Exp. 1, the route drawing were scored based on five elements: the correct identification of the starting point (1 point) and destination (1 point), recurrence of cancelling lines (1 point for no hesitation, 0.5 for up to three lines, a score of zero for more than three lines), if they drew all five streets of the route (1 point for each street), if they drew exactly the route as taught without mistakes also they would be awarded one, if they had one to three mistakes 0.5 and for four or more mistakes they would be awarded zero. The maximum score achievable in Exp. 1 was nine.

In Exp.2, the score given for the route drawing was based on four elements: the start point (1 point), the end point (1 point), the correct labelling of the start and the end point (1 point), and the route accuracy (1 point) in which they acknowledged that they had to walk through the route seven times. The maximum score possible was four.

In both experiments, the participants were also asked to list as many landmarks seen in the game as they could. The landmarks recalled were counted and one point was assigned for each one mentioned. The possible landmarks for Exp.1 were buildings located on both sides of the road, garden, car park etc., for a total of seven possible points. For Exp.2 the landmarks were the Safa hill (start point), the Marwah hill (end point), the Kaabah (black cuboid) etc., for a total of nine possible points.

6.2.2.3 Criterion 3: Perform ritual actions

As mentioned in Section 6.2.2.1, participants were video recorded while walking the route in the indoor area . Their performance accuracy was scored based on two major elements: i) Compulsory Actions, these were six possible actions (6 points) (e.g. begin the ritual from Safa hill) and ii) Optional Actions. There were ten possible actions (10 points) (e.g. go over the hill of Safa). The maximum score for this criterion was sixteen.

6.2.2.4 Learning performance score

In Exp. 1, the maximum score available across two criteria was 1 + 9 = 10 points. The maximum number of landmarks was 7; as such, each participant could be awarded a maximum of 17 points for the learning performance.

In Exp. 2, considering the three criteria, the maximum score was 3 + 4 + 16 = 23. The maximum number of landmarks was 9; as such, each participant could be awarded a maximum of 32 points for the learning performance.

6.3 Experiment 1

6.3.1 Results

6.3.1.1 Mood before and after the learning task

The *'overall mood'* of participants before and after the learning task was then analysed. Before the task, ten participants (27.78%) felt *'very pleasant'*, nineteen (52.78%) felt *'pleasant'* and another seven (19.44%) felt *'unpleasant'*. The average *'overall mood'* was 3.08 (Table 6.1).

After performing the task, fourteen (38.89%) felt *'very pleasant'*, twenty-one participants (58.33%) felt *'pleasant'* and one participant (2.78%) felt *'unpleasant'*. The average *'overall mood'* after the task was 3.36 (Table 6.1).

The moods at pre- and post-learning times were compared to identify any differences. As the data was not normally distributed, the Wilcoxon test was used and also, to check whether the mean ranks varies. The results of the pre- and post-*'overall mood'* show that after learning, the applied game has significantly improved participants' mood ($W = 19.5$, $p = .025$) (Table 6.1).

No significant difference was found for participants' *'tired'* or *'fed up'* score before and after playing the game. However, learning a route (i.e. familiarise and travel) in the applied game significantly increased participants' *'happy'* score ($W = 6$, $p = .005$) (Table 6.1). Out of the 36, 11 participants (30.56%) felt happier after learning to travel in the game environment. Of those, 8 were men and 3 were women.

The average time spent to complete the learning tasks was 3 minutes and 10 seconds, however, considering the participants who felt happier, 5 of them spent more than the

Table 6.1: Average of pre- and post-mood (Exp. 1)

Average	Pre	Post
Overall	3.08	3.36
Happy	3.17	3.47

average time in the game (up to 2 minutes).

6.3.1.2 *'Happy'* mood and scored learning performance

The score obtained in the learning performance by the 36 participants was considered. The average score obtained was 11.17 over the 17 points possible. Fourteen participants (38.89%) obtained a score below the average and these were 4 males and 10 females. Of these 14, 7 participants (50%) gained below 8 and these were all females who also did not report an increase in happiness after playing the game.

Feeling happier after playing the game did not have a significant influence on the learning performance, however, the data show some trends (Table 6.2). All participants performed well, but in particular, the score was higher if they felt happier, and this trend was true across all the elements considered in the score.

Table 6.2: Learning performance score (Exp. 1)

	Midpoint	Overall average	Average of participants with no mood difference	Average of happier participant
Learning performance score	8.5	11.17	10.82	11.95
Real world navigation element	0.5	0.92	0.88	1
Route drawing element	4.5	7.14	6.98	7.5
Landmarks recall element	3.5	3.11	2.96	3.45

6.3.1.3 *'Happy'* mood and self-reported learning experience

After the experiment, participants were required to comment on the gaming experience. In the questionnaire responses, all but two participants (34/36 – 94.44%) reported to have found the game *'interesting'* (the average score was 4.5/5) and 25 out of 36 participants (69.44%) found that it was *'easy'* to find a signpost in the environment (the average score was 3.78/5), despite some of them were not happier after playing the game.

In the free text comment section, all players with the increased *'happy'* score reported that they really liked the game, and enjoyed learning and travelling in the environment because it felt real and was easy to navigate. Those who did not report an increased *'happy'* score still commented that the learning experience was interesting and the world was easy to navigate, see Section 6.3.1.4. As such, we conclude that the game and the learning experience in itself were the cause of the participants' increased happiness.

6.3.1.4 Participants' comments

At the end of the experiment, participants were asked to comment in a free text box. The relevant comments are described below:

Comments about the mood
C1: "It was an interesting environment and I felt so excited."
C2: "The game was really real and amazing. I felt excited doing the navigation task and I liked it much."

Comments about the learning performance
C3: "I got familiar with the environment easily and it was easy to recall."
C4: "It was easy to remember the landmarks."
C5: "I liked the game because it was easy to navigate and recall (less information and simulated what was necessary only)."

Comments about the learning experience
C6: "Game was the best to get involved."
C7: "It was easy to navigate which motivated me to finish the task."
C8: "It was easy to learn as it simulated necessary landmarks only (it reduced the information)."
C9: "Easy to navigate."
C10: "I liked the game as it was easy to find the route and follow the directions."
C11: "I really liked the game as it was real and amazing (immersed in the environment)."

6.4 Experiment 2

6.4.1 Results

6.4.1.1 Mood before and after the learning task

The *'overall mood'* of participants before and after the learning task was analysed. Before playing the game, the players' mood can be considered as mixed moods; in which five participants (31.25%) felt *'very pleasant'*, six (37.5%) felt *'pleasant'*, four (25%) felt *'unpleasant'*, and one (6.25%) felt *'very unpleasant'*, with an average *'overall mood'* of 2.94 (Table 6.3).

After the learning task, everyone, but two participants felt *'very pleasant'* or *'pleasant'*; of which eight participants (50%) felt *'very pleasant'*, six (37.5%) felt *'pleasant'*, one

(6.25%) felt *'unpleasant'* and one (6.25%) felt *'very unpleasant'* (these two volunteers did not change the score from pre-test), with an average *'overall mood'* of 3.31 (Table 6.3).

The moods at pre- and post-learning times were compared to identify any differences using the same test as in Exp. 1. The results of the pre- and post-*'overall mood'* show that after learning with the applied game, the players' mood has significantly improved ($W = 0$, $p = .014$) (Table 6.3).

No significant difference was found for participants' *'tired'* or *'fed up'* scores before and after playing the game. However, learning Sa'ie ritual in the applied game significantly increased participants' *'happy'* score ($W = 0$, $p = .008$) (Table 6.3). Of the 16 participants, 7 people (43.75%) felt happier after learning how to perform the Sa'ie from the game. Of those, 3 were men and 4 were women.

Table 6.3: Average of pre- and post-mood (Exp. 2)

Average	**Pre**	**Post**
Overall	2.94	3.31
Happy	2.94	3.38

The average time spent to complete the learning task was 12 minutes and 10 seconds, however, considering the participants who felt happier, 5 of them spent up to 5 minutes more than the average time in the game, suggesting that there is a relationship between the time spent playing and the *'happy'* score.

6.4.1.2 *'Happy'* mood and scored learning performance

For all the 16 participants, the average score of learning performance was 21.55 over the 32 possible points. Seven participants (43.75%) obtained a score below the average; and these were 4 males and 3 females.

Feeling happier after playing the game did not have a significant influence on the learning performance; however, the data show some trends (Table 6.4). All participants performed well, but in particular, the score was higher if they felt happier. For this game, considering the individual elements of the score, the landmarks recall did not match with the same trend as the learning performance.

6.4.1.3 *'Happy'* mood and self-reported learning experience

In the post-questionnaire, all 16 participants agreed that the learning material (game and content) presented was *'interesting'* (the average score was 4.88/5) and 'helpful' (the average score was 4.75/5). The findings moreover were reinforced by the explanations provided in the comment section, see Section 6.4.1.4.

Table 6.4: Learning performance score (Exp. 2)

	Midpoint	**Overall average**	**Average of participants with no mood difference**	**Average of happier participant**
Learning performance score	16	21.55	20.75	22.57
Real world navigation element	9.5	12.7	11.89	13.75
Route drawing element	2	2.84	2.64	3.1
Landmarks recall element	4.5	6	6.22	5.71

6.4.1.4 Participants' comments

After the experiment, participants were asked to write their comments in a free text box. The relevant comments are described as follows:

Comments about the mood
C1: "It set me free from study stress at that time."
C2: "The game was different and new. Learning (while moving) and playing together increased excitement."
C3: "As a gamer, I already felt excited before learning. I could not imagine learning religious things in the game. Super cool, and I really liked it."
C4: "I was so interested in religious things and curious to know how the Sa'ie game looked like. I felt being in real Masjidil Haram when playing the game. I felt satisfied after playing and learning from this game."
C5: "I liked the idea of transformation Sa'ie learning into the game-based learning. I felt happy while playing and even after."
C6: "I was surprised at the beginning when seeing this game. I do not like to play video games. I felt happy after playing this game as learning something good from it, not just playing common video games."
C7: "I was so excited when playing this game. I moved in the environment where I had not seen before in real. This game was simple and not hard to play but informed the knowledge."

Comments about the learning performance
C8: "It was very fun to learn using the game, as it made me remembered more things than just learning by PowerPoint slide or normal lecture."

Comments about the learning experience
C9: "This game helped me to learn new knowledge about Sa'ie and strengthen my individual knowledge specifically."
C10: "I found the game of Sa'ie was very informative as it introduced an entertaining

style to learn how to perform Sa'ie. Overall, it was a pleasant experience."

6.5 Findings of the Combined Experiments

6.5.1 All Participants

Looking at the 52 subjects across the two experiments, they were gender balanced, their average age was 28.69, and the majority participants have good to very good spatial and navigational abilities (42/52 – 80.77%).

It was tested on whether the mean of gender, spatial and navigational abilities and mood had any relationship with the learning performance mean using the one-way ANOVA as the data was normally distributed, and it was found that there was no significant difference. However, there was a significant difference between age categories (F (2, 49) = 3.755, p = .030) (Table 6.5). A Tukey post hoc test indicated that learning performance score was significantly higher if participants were in 18-24 age category as compared to those in the age category of 25-34 (p = .040), suggesting that younger users achieved a higher learning performance score following a serious gameplay.

Table 6.5: Learning performance score by age

Age category	Total participants	Learning performance average
18-24	12	18.16
25-34	34	13.44
35-44	6	12

From the 18/52 participants who indicated that they felt happier after playing the applied game, more males (11/18 – 61%) reported an increase in the 'happy' score as compared to females (7/18 – 39%). This is in line with the finding in the literature that men enjoy playing games more than women.

6.5.2 Participants by Gender

As the data was normally dispersed, the t-test was used to check if there was a relationship between the mean of age, spatial and navigational abilities, and 'overall mood'; and the learning performance mean for both genders, but no significant difference was found. The relationship between happiness and learning performance for men was checked and also, no significant difference was found. However, in the case of women, it was found that happier women had a significantly higher learning performance score as compared to those who had no mood improvement (t (24) = -2.618, p = 0.015) (Table 6.6).

Participants' self-scored spatial and navigational abilities were compared between genders using the t-test and it was found that there was a significant difference, in which men had higher abilities score than women (t (50) = 3.611, p = 0.001) (Table 6.7).

Table 6.6: Learning performance score by gender and happiness

Gender	Overall average	Average of participants with no mood difference	Average of happier participant
Men	14.68	15.15	14.04
Women	14.04	12.1	19.29

Table 6.7: Spatial and navigational abilities

Overall average	Average of men	Average of women
3.53	3.81	3.24

6.6 Discussion

For this study, two serious games have been considered, one of which learners learned the way to find a specific location in the real world, while in the other one, learners learned a religious ritual. Playing both games involved navigation in a virtual environment as the main action to acquire the knowledge taught by the game. Moreover, the games did not have a lot of traditional game features, such as scores, winner chart, splash screen or mood setting narrative to encourage the players to proceed with the gameplay.

It was found that it was possible to influence participants' mood by playing a serious game, and both serious games pleasantly enhanced the 'overall mood' of players and improved their happiness at the end of the learning session. By looking at both games, it was found that a positive mood during gameplay significantly influenced the learning performance score of women. However, in general, the data show that the score tends to be higher if they felt happier. In addition, it was found that younger players had a higher score of learning performance after learning from serious gameplay.

There was no significant relationship when considering the participants' gender; however, more men were reported to be happier as compared to women, a finding which is in line with the literature. Apart from that, according to self-reported score, men obtained a significantly higher score in the spatial and navigational abilities test.

As both games involved navigation in a virtual environment that had several visually interesting features and provided experiential learning, it is speculated that this was one of the reasons why most players who felt happier, spent their time longer than average playing the games. This is supported by the participants' comments who found the learning experience was interesting and informative, and that the games helped them to understand the knowledge better in an exciting environment.

6.7 Conclusion

Serious games are different from video games which are created for mere entertainment. As the focus is to achieve a given learning objective, they might have less rewarding features (such as points, badges, winner scores, etc.) as compared to video games. In this chapter, the findings from the previous experiments were collated and investigated for any new pattern. The findings indicate that serious games that involved navigation in an interesting and exciting environment (i.e. visual features and informative content) significantly induced a positive mood improvement in the players. In addition, happy players spent more time in the learning environment. Women who were happier after playing and younger players also tend to obtain a higher learning performance score. The findings, therefore, support the idea that serious games are a valid instruction method to be used by teachers to achieve the desired learning outcomes, while at the same time improve the students' mood.

6.8 End-of-chapter Summary

In short, navigation in serious games that simulate an interesting and exciting environment induces positive mood improvement in the players. Women with increased happiness and younger players tend to obtain a higher learning performance score after playing a serious game.

Chapter 7

Conclusions

Contents

This chapter summarises the research findings and its implications for teaching and learning, and proposes some future work that can be further explored. The chapter also concludes with a self-reflection on the work conducted.

7.1 Research Conclusions

The purposes of Study 1 were to investigate the need of a three-dimensional virtual environment to learn a route in the real world, to find a better modality in following the navigation instructions and to examine short-term memory following the task (see Chapter 4). In Study 2, the purposes were to review the efficiency of a serious game to learn a set of ritual procedure as compared to PowerPoint note, to check the need of a coach to enhance learning performance, to investigate the efficacy of learners' memory in a short and long-term period and to find gender differences while learning a ritual (see Chapter 5). Also, the results from both experiments were combined, and the further results were obtained (see Chapter 6). Therefore, with regards to the six elements investigated in this research work, the following conclusions are made.

1. Knowledge representations in procedural learning

    - 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
- PowerPoint note can be used to learn factual knowledge in ritual learning
- Younger players improve learning performance after learning in a virtual environment and serious game

2. Optimal instruction modalities for learning navigation skills and ritual

   - Having a companion to the task is a better instruction modality to learn a new route
   - Having a companion to a ritual learning increases users' happiness
   - Having a coach improves users' learning efficiency and moods

3. Mood and learning in navigation-based virtual environment and serious game

   - 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

4. Transfer of knowledge from virtual training to real world

   - 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

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

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

6. Gender differences

   - Men recognise routes better than women
   - Men take less time to complete a ritual learning
   - Ritual learning with a companion decrease men's tiredness
   - Ritual learning with a companion improve women's overall mood
   - Women feel that the task is more enjoyable when learning with a companion
   - Women recall more landmarks than men

7.2 Implications for Teaching and Learning

Following this research investigation, the use of virtual environments and serious games for teaching procedures that involve navigation is recommended. Improved mood, enjoyment and the creation of interesting experience are some of the justification for their use. Also, 3D representations encourage memorization of important landmarks. Finally, collaborative learning is more fun, and when the learning is with a coach, it is more helpful.

Considering the Sa'ie learning, participants gained factual knowledge better after learning from the PowerPoint note and correctly responded to the quiz. However, learning from the serious game encouraged memorising the 3D spatial representations and the key landmarks in Mas'a, which is a considerably important skill needed to perform the Sa'ie ritual in real life correctly. The memorization is a significant advantage as learners can absorb and retain the acquired skill longer, and they are able to put it in practice even after a while. Learning practical ritual skills, virtual environments (or serious games) provide better training and can be complemented by textual and visual information if there is need to provide further factual knowledge. This factual knowledge could also be included more prominently in the game, and gamification (for example, in the form of rewards) might further encourage learners to pay attention to the textual information provided.

7.3 Future Work

The work presented in this thesis can be extended by considering further elements from both experiments and opening up new research questions. The short-term plan is to investigate the data obtained from both studies by combining some variables for further research findings. The development of the Sa'ie game is continued by adding more traditional game elements, and the new prototype could be further evaluated and compared with other learning methods.

In the long-term plan, research works in procedural learning could investigate further elements that might support learning, such as the utilisation of 3D avatars to replace a real companion, the addition of a crowd simulation to the Sa'ie game, and also, the effects of these elements on learning, knowledge delivery and transfer, and mood. The field of rituals teaching could also benefit from investigating virtual environments and serious games delivery of other rituals. Also, it would be good to observe whether the improved mood is obtained only from serious games or it is connected to generic navigation-based games.

7.4 Self-Reflections

Some reflections based on experience undergone in the last four years are provided below in the trust that these could be useful to other researchers:

- Figure out clear research gaps as early as possible
- Renew motivations along the journey and keep up the work hard
- Time management: be quick and punctual
- Seek opportunities to enhance knowledge and skills (e.g. learn how to use new software or programming languages, or new techniques)

- Keep reading the literature
- Improve writing skills by writing regularly and receiving feedback from supervisor and peers
- Recruit a large number of participants for the experiments, so that the findings are solid.

Bibliography

[1] L. Gamberini, L. Chittaro, A. Spagnolli, and C. Carlesso, “Psychological response to an emergency in virtual reality: Effects of victim ethnicity and emergency type on helping behavior and navigation,” *Computers in human behavior*, vol. 48, pp. 104–113, 2015.

[2] P. T. Chua, R. Crivella, B. Daly, N. Hu, R. Schaaf, D. Ventura, T. Camill, J. Hodgins, and R. Pausch, “Training for physical tasks in virtual environments: Tai chi,” in *Virtual Reality, 2003. Proceedings. IEEE*, pp. 87–94, IEEE, 2003.

[3] H.-M. Huang, U. Rauch, and S.-S. Liaw, “Investigating learners’ attitudes toward virtual reality learning environments: Based on a constructivist approach,” *Computers & Education*, vol. 55, no. 3, pp. 1171–1182, 2010.

[4] T. A. Mikropoulos and A. Natsis, “Educational virtual environments: A ten-year review of empirical research (1999–2009),” *Computers & Education*, vol. 56, no. 3, pp. 769–780, 2011.

[5] W. Winn, “A conceptual basis for educational applications of virtual reality,” *Technical Publication R-93-9, Human Interface Technology Laboratory of the Washington Technology Center, Seattle: University of Washington*, 1993.

[6] J. Piaget, *The construction of reality in the child*, vol. 82. Routledge, 2013.

[7] C. R. Rogers, *Learning to be free.* Pacifica Tape Library, 1983.

[8] C. R. Rogers and H. J. Freiberg, *Freedom to learn.* OH: Merrill Columbus, 1969.

[9] J. Dewey, *Democracy and education.* Courier Corporation, 2004.

[10] D. A. Kolb, *Experiential learning: Experience as the source of learning and development.* FT press, 2014.

[11] L. Vygotsky, “Interaction between learning and development,” *Readings on the development of children*, vol. 23, no. 3, pp. 34–41, 1978.

[12] J. R. Savery and T. M. Duffy, “Problem based learning: An instructional model and its constructivist framework,” *Educational technology*, vol. 35, no. 5, pp. 31–38, 1995.

[13] R. E. Mayer, "Should there be a three-strikes rule against pure discovery learning?," *American psychologist*, vol. 59, no. 1, p. 14, 2004.

[14] R. M. Baños, C. Botella, A. Garcia-Palacios, H. Villa, C. Perpiñá, and M. Alcaniz, "Presence and reality judgment in virtual environments: a unitary construct?," *CyberPsychology & Behavior*, vol. 3, no. 3, pp. 327–335, 2000.

[15] M. Usoh, E. Catena, S. Arman, and M. Slater, "Using presence questionnaires in reality," *Presence: Teleoperators and Virtual Environments*, vol. 9, no. 5, pp. 497–503, 2000.

[16] Z. Pan, A. D. Cheok, H. Yang, J. Zhu, and J. Shi, "Virtual reality and mixed reality for virtual learning environments," *Computers & Graphics*, vol. 30, no. 1, pp. 20–28, 2006.

[17] E. Ye, Y. Fang, C. Liu, T. J. Chang, and H. Q. Dinh, "Appalachian tycoon: an environmental education game in second life," in *Second Life Education Workshop 2007*, p. 72, 2007.

[18] I. Machado, P. Brna, and A. Paiva, "Tell me a story," *Virtual Reality*, vol. 9, no. 1, pp. 34–48, 2005.

[19] A. Johnson, T. Moher, S. Ohlsson, and M. Gillingham, "The round earth project-collaborative vr for conceptual learning," *IEEE Computer Graphics and Applications*, vol. 19, no. 6, pp. 60–69, 1999.

[20] M. Roussos, A. Johnson, T. Moher, J. Leigh, C. Vasilakis, and C. Barnes, "Learning and building together in an immersive virtual world," *Presence: Teleoperators and Virtual Environments*, vol. 8, no. 3, pp. 247–263, 1999.

[21] H.-M. Huang, "Toward constructivism for adult learners in online learning environments," *British Journal of Educational Technology*, vol. 33, no. 1, pp. 27–37, 2002.

[22] E. Van Wyk and R. De Villiers, "Virtual reality training applications for the mining industry," in *Proceedings of the 6th international conference on computer graphics, virtual reality, visualisation and interaction in Africa*, pp. 53–63, ACM, 2009.

[23] E. Van Wyk and R. De Villiers, "Usability context analysis for virtual reality training in south african mines," in *Proceedings of the 2008 annual research conference of the South African Institute of Computer Scientists and Information Technologists on IT research in developing countries: riding the wave of technology*, pp. 276–285, ACM, 2008.

[24] T. Cooper, "Nutrition game," in *Proceedings of the Second Life education workshop*, pp. 47–50, Citeseer, 2007.

[25] L. Nelson, L. Sadler, and G. Surtees, "Bringing problem based learning to life using virtual reality," *Nurse Education in Practice*, vol. 5, no. 2, pp. 103–108, 2005.

[26] J. R. Anderson, L. M. Reder, and H. A. Simon, “Situated learning and education,” *Educational researcher*, vol. 25, no. 4, pp. 5–11, 1996.

[27] M. F. Young, “Instructional design for situated learning,” *Educational technology research and development*, vol. 41, no. 1, pp. 43–58, 1993.

[28] M. Bricken, “Virtual reality learning environments: potentials and challenges,” *ACM SIGGRAPH Computer Graphics*, vol. 25, no. 3, pp. 178–184, 1991.

[29] L. Chittaro and R. Ranon, “Web3d technologies in learning, education and training: Motivations, issues, opportunities,” *Computers & Education*, vol. 49, no. 1, pp. 3–18, 2007.

[30] G. Hokanson, O. Borchert, B. M. Slator, J. Terpstra, J. T. Clark, L. M. Daniels, H. R. Anderson, A. Bergstrom, T. A. Hanson, J. Reber, *et al.*, “Studying native american culture in an immersive virtual environment,” in *Advanced Learning Technologies, 2008. ICALT’08. Eighth IEEE International Conference on*, pp. 788–792, IEEE, 2008.

[31] J. E. Brough, M. Schwartz, S. K. Gupta, D. K. Anand, R. Kavetsky, and R. Pettersen, “Towards the development of a virtual environment-based training system for mechanical assembly operations,” *Virtual Reality*, vol. 11, no. 4, pp. 189–206, 2007.

[32] M. Roussou, M. Oliver, and M. Slater, “The virtual playground: an educational virtual reality environment for evaluating interactivity and conceptual learning,” *Virtual reality*, vol. 10, no. 3-4, pp. 227–240, 2006.

[33] A. Pasqualotti and C. M. d. S. Freitas, “MAT3D: a virtual reality modeling language environment for the teaching and learning of mathematics,” *CyberPsychology & Behavior*, vol. 5, no. 5, pp. 409–422, 2002.

[34] J. K. Crosier, S. V. Cobb, and J. R. Wilson, “Experimental comparison of virtual reality with traditional teaching methods for teaching radioactivity,” *Education and Information Technologies*, vol. 5, no. 4, pp. 329–343, 2000.

[35] C. Dede, M. C. Salzman, R. B. Loftin, and D. Sprague, “Multisensory immersion as a modeling environment for learning complex scientific concepts,” in *Modeling and simulation in science and mathematics education*, pp. 282–319, Springer, 1999.

[36] A. M. Kontogeorgiou, J. Bellou, and T. A. Mikropoulos, “Being inside the quantum atom.,” *PsychNology Journal*, vol. 6, no. 1, pp. 83–98, 2008.

[37] M. Limniou, D. Roberts, and N. Papadopoulos, “Full immersive virtual environment cave tm in chemistry education,” *Computers & Education*, vol. 51, no. 2, pp. 584–593, 2008.

[38] C.-H. Chen, J.-C. Yang, S. Shen, and M.-C. Jeng, "A desktop virtual reality earth motion system in astronomy education," *Educational Technology & Society*, vol. 10, no. 3, pp. 289–304, 2007.

[39] J. Wu, E. Mattingly, and P. Kraemer, "Communication in virtual environments: The influence of spatial cues and gender on verbal behavior," *Computers in Human Behavior*, vol. 52, pp. 59–64, 2015.

[40] S. A. Barab, T. D. Sadler, C. Heiselt, D. Hickey, and S. Zuiker, "Relating narrative, inquiry, and inscriptions: Supporting consequential play," *Journal of science education and technology*, vol. 16, no. 1, pp. 59–82, 2007.

[41] H. Tüzün, M. Yılmaz-Soylu, T. Karakuş, Y. İnal, and G. Kızılkaya, "The effects of computer games on primary school students' achievement and motivation in geography learning," *Computers & Education*, vol. 52, no. 1, pp. 68–77, 2009.

[42] N. Adamo-Villani and R. B. Wilbur, "Effects of platform (immersive versus non-immersive) on usability and enjoyment of a virtual learning environment for deaf and hearing children," in *Proc. of EGVE*, 2008.

[43] P. Marshall, Y. Rogers, and M. Scaife, "Puppet: playing and learning in a virtual world," *International Journal of Continuing Engineering Education and Life Long Learning*, vol. 14, no. 6, pp. 519–531, 2004.

[44] T. A. Mikropoulos and V. Strouboulis, "Factors that influence presence in educational virtual environments," *CyberPsychology & Behavior*, vol. 7, no. 5, pp. 582–591, 2004.

[45] B. C. Nelson and D. J. Ketelhut, "Exploring embedded guidance and self-efficacy in educational multi-user virtual environments," *International Journal of Computer-Supported Collaborative Learning*, vol. 3, no. 4, pp. 413–427, 2008.

[46] B. C. Nelson, "Exploring the use of individualized, reflective guidance in an educational multi-user virtual environment," *Journal of Science Education and Technology*, vol. 16, no. 1, pp. 83–97, 2007.

[47] D. J. Ketelhut, "The impact of student self-efficacy on scientific inquiry skills: An exploratory investigation in river city, a multi-user virtual environment," *Journal of Science Education and Technology*, vol. 16, no. 1, pp. 99–111, 2007.

[48] R. Zajtchuk and R. M. Satava, "Medical applications of virtual reality," *Communications of the ACM*, vol. 40, no. 9, pp. 63–64, 1997.

[49] M. Bajka, S. Tuchschmid, M. Streich, D. Fink, G. Székely, and M. Harders, "Evaluation of a new virtual-reality training simulator for hysteroscopy," *Surgical endoscopy*, vol. 23, no. 9, p. 2026, 2009.

[50] J. N. Howell, R. R. Conatser, R. L. Williams, J. M. Burns, and D. C. Eland, "The virtual haptic back: a simulation for training in palpatory diagnosis," *BMC medical education*, vol. 8, no. 1, p. 14, 2008.

[51] K. Tanoue, S. Ieiri, K. Konishi, T. Yasunaga, K. Okazaki, S. Yamaguchi, D. Yoshida, Y. Kakeji, and M. Hashizume, "Effectiveness of endoscopic surgery training for medical students using a virtual reality simulator versus a box trainer: a randomized controlled trial," *Surgical endoscopy*, vol. 22, no. 4, pp. 985–990, 2008.

[52] J. Holmes, "Designing agents to support learning by explaining," *Computers & Education*, vol. 48, no. 4, pp. 523–547, 2007.

[53] J. Steuer, "Defining virtual reality: Dimensions determining telepresence," *Journal of communication*, vol. 42, no. 4, pp. 73–93, 1992.

[54] G. C. Burdea and P. Coiffet, *Virtual reality technology*, vol. 1. John Wiley & Sons, 2003.

[55] J. Caird, "Persistent issues in the application of virtual environment systems to training," in *Human Interaction with Complex Systems, 1996. HICS'96. Proceedings., Third Annual Symposium on*, pp. 124–132, IEEE, 1996.

[56] M. Chessa, G. Maiello, A. Borsari, and P. J. Bex, "The perceptual quality of the oculus rift for immersive virtual reality," *Human–Computer Interaction*, pp. 1–32, 2016.

[57] C. Cruz-Neira, D. J. Sandin, and T. A. DeFanti, "Surround-screen projection-based virtual reality: the design and implementation of the cave," in *Proceedings of the 20th annual conference on Computer graphics and interactive techniques*, pp. 135–142, ACM, 1993.

[58] M. P. McCreery, P. Schrader, S. K. Krach, and R. Boone, "A sense of self: The role of presence in virtual environments," *Computers in Human Behavior*, vol. 29, no. 4, pp. 1635–1640, 2013.

[59] M. Slater, "How colorful was your day? why questionnaires cannot assess presence in virtual environments," *Presence: Teleoperators and Virtual Environments*, vol. 13, no. 4, pp. 484–493, 2004.

[60] M. Slater, "Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments," *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, vol. 364, no. 1535, pp. 3549–3557, 2009.

[61] M. V. Sanchez-Vives and M. Slater, "From presence to consciousness through virtual reality," *Nat Rev Neurosci*, vol. 6, no. 4, pp. 332–339, 2005.

[62] H. S. Wallach, M. P. Safir, and I. Almog, "Attachment and sense of presence in a virtual environment," *Virtual reality*, vol. 13, no. 3, pp. 205–217, 2009.

[63] M. P. McCreery, S. K. Krach, P. Schrader, and R. Boone, "Defining the virtual self: Personality, behavior, and the psychology of embodiment," *Computers in Human Behavior*, vol. 28, no. 3, pp. 976–983, 2012.

[64] M. Slater and S. Wilbur, "A framework for immersive virtual environments (five): Speculations on the role of presence in virtual environments," *Presence: Teleoperators and virtual environments*, vol. 6, no. 6, pp. 603–616, 1997.

[65] H. L. Miller and N. L. Bugnariu, "Level of immersion in virtual environments impacts the ability to assess and teach social skills in autism spectrum disorder," *Cyberpsychology, Behavior, and Social Networking*, vol. 19, no. 4, pp. 246–256, 2016.

[66] K. Mania and A. Chalmers, "The effects of levels of immersion on memory and presence in virtual environments: A reality centered approach," *CyberPsychology & Behavior*, vol. 4, no. 2, pp. 247–264, 2001.

[67] U. Yang and G. J. Kim, "Implementation and evaluation of "just follow me": an immersive, vr-based, motion-training system," *Presence: Teleoperators and Virtual Environments*, vol. 11, no. 3, pp. 304–323, 2002.

[68] R. A. Ruddle, S. J. Payne, and D. M. Jones, "The effects of maps on navigation and search strategies in very-large-scale virtual environments.," *Journal of Experimental Psychology: Applied*, vol. 5, no. 1, p. 54, 1999.

[69] L. Chittaro and R. Ranon, "Serious games for training occupants of a building in personal fire safety skills," in *Games and Virtual Worlds for Serious Applications, 2009. VS-GAMES'09. Conference in*, pp. 76–83, IEEE, 2009.

[70] P. Henry, C. Vollmer, B. Ferris, and D. Fox, "Learning to navigate through crowded environments," in *Robotics and Automation (ICRA), 2010 IEEE International Conference on*, pp. 981–986, IEEE, 2010.

[71] J. Sánchez, M. Sáenz, A. Pascual-Leone, and L. Merabet, "Navigation for the blind through audio-based virtual environments," in *CHI'10 Extended Abstracts on Human Factors in Computing Systems*, pp. 3409–3414, ACM, 2010.

[72] R. A. Ruddle, S. J. Payne, and D. M. Jones, "Navigating large-scale virtual environments: What differences occur between helmet-mounted and desk-top displays?," *Presence: Teleoperators and Virtual Environments*, vol. 8, no. 2, pp. 157–168, 1999.

[73] D. Waller, "The WALKABOUT: Using virtual environments to assess large-scale spatial abilities," *Computers in human behavior*, vol. 21, no. 2, pp. 243–253, 2005.

[74] R. A. Ruddle, S. J. Payne, and D. M. Jones, "Navigating buildings in" desk-top" virtual environments: Experimental investigations using extended navigational experience.," *Journal of Experimental Psychology: Applied*, vol. 3, no. 2, p. 143, 1997.

[75] L. Castelli, L. L. Corazzini, and G. C. Geminiani, "Spatial navigation in large-scale virtual environments: Gender differences in survey tasks," *Computers in Human behavior*, vol. 24, no. 4, pp. 1643–1667, 2008.

[76] A. E. Richardson, M. E. Powers, and L. G. Bousquet, "Video game experience predicts virtual, but not real navigation performance," *Computers in Human Behavior*, vol. 27, no. 1, pp. 552–560, 2011.

[77] T. T. Brunyé, A. Gardony, C. R. Mahoney, and H. A. Taylor, "Going to town: Visualized perspectives and navigation through virtual environments," *Computers in Human Behavior*, vol. 28, no. 1, pp. 257–266, 2012.

[78] P. Jansen-Osmann, "Using desktop virtual environments to investigate the role of landmarks," *Computers in Human behavior*, vol. 18, no. 4, pp. 427–436, 2002.

[79] D. R. Michael and S. L. Chen, *Serious games: Games that educate, train, and inform.* Muska & Lipman/Premier-Trade, 2005.

[80] M. Agogué, K. Levillain, and S. Hooge, "Gamification of creativity: Exploring the usefulness of serious games for ideation," *Creativity and Innovation Management*, vol. 24, no. 3, pp. 415–429, 2015.

[81] T. M. Fleming, L. Bavin, K. Stasiak, E. Hermansson-Webb, S. N. Merry, C. Cheek, M. Lucassen, H. M. Lau, B. Pollmuller, and S. Hetrick, "serious games and gamification for mental health: current status and promising directions," *Frontiers in Psychiatry*, vol. 7, 2016.

[82] B. Gros, "Digital games in education: The design of games-based learning environments," *Journal of research on technology in education*, vol. 40, no. 1, pp. 23–38, 2007.

[83] K. Seaborn and D. I. Fels, "Gamification in theory and action: A survey," *International Journal of Human-Computer Studies*, vol. 74, pp. 14–31, 2015.

[84] M. J. Dondlinger, "Educational video game design: A review of the literature," *Journal of applied educational technology*, vol. 4, no. 1, pp. 21–31, 2007.

[85] E. Boyle, T. M. Connolly, and T. Hainey, "The role of psychology in understanding the impact of computer games," *Entertainment Computing*, vol. 2, no. 2, pp. 69–74, 2011.

[86] M. Muratet, P. Torguet, J.-P. Jessel, and F. Viallet, "Towards a serious game to help students learn computer programming," *International Journal of Computer Games Technology*, vol. 2009, p. 3, 2009.

[87] C. S. Green and D. Bavelier, "Enumeration versus multiple object tracking: The case of action video game players," *Cognition*, vol. 101, no. 1, pp. 217–245, 2006.

[88] K. Durkin and B. Barber, “Not so doomed: Computer game play and positive adolescent development,” *Journal of applied developmental psychology*, vol. 23, no. 4, pp. 373–392, 2002.

[89] S. Deterding, D. Dixon, R. Khaled, and L. Nacke, “From game design elements to gamefulness: defining gamification,” in *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments*, pp. 9–15, ACM, 2011.

[90] I. Boughzala and H. Michel, “Introduction to the serious games, gamification and innovation minitrack,” in *System Sciences (HICSS), 2016 49th Hawaii International Conference on*, pp. 817–817, IEEE, 2016.

[91] S. Arnab, K. Brown, S. Clarke, I. Dunwell, T. Lim, N. Suttie, S. Louchart, M. Hendrix, and S. De Freitas, “The development approach of a pedagogically-driven serious game to support relationship and sex education (rse) within a classroom setting,” *Computers & Education*, vol. 69, pp. 15–30, 2013.

[92] F. Xu, D. Buhalis, and J. Weber, “Serious games and the gamification of tourism,” *Tourism Management*, vol. 60, pp. 244–256, 2017.

[93] J. Hamari and J. Tuunanen, “Player types: A meta-synthesis,” *Transactions of the Digital Games Research Association*, vol. 1, no. 2, 2014.

[94] D. Johnson, E. Horton, R. Mulcahy, and M. Foth, “Gamification and serious games within the domain of domestic energy consumption: A systematic review,” *Renewable and Sustainable Energy Reviews*, vol. 73, pp. 249–264, 2017.

[95] S. Nicholson, “A recipe for meaningful gamification,” in *Gamification in education and business*, pp. 1–20, Springer, 2015.

[96] O. Pedreira, F. García, N. Brisaboa, and M. Piattini, “Gamification in software engineering–a systematic mapping,” *Information and Software Technology*, vol. 57, pp. 157–168, 2015.

[97] D. J. Shernoff, M. Csikszentmihalyi, B. Shneider, and E. S. Shernoff, “Student engagement in high school classrooms from the perspective of flow theory.,” *School Psychology Quarterly*, vol. 18, no. 2, p. 158, 2003.

[98] D. Ó. Broin, “Using a criteria-based user model for facilitating flow in serious games,” in *Games and Virtual Worlds for Serious Applications (VS-GAMES), 2011 Third International Conference on*, pp. 63–69, IEEE, 2011.

[99] J. Hamari, D. J. Shernoff, E. Rowe, B. Coller, J. Asbell-Clarke, and T. Edwards, “Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning,” *Computers in Human Behavior*, vol. 54, pp. 170–179, 2016.

[100] R. Hunicke, M. LeBlanc, and R. Zubek, “Mda: A formal approach to game design and game research,” in *Proceedings of the AAAI Workshop on Challenges in Game AI*, vol. 4, 2004.

[101] C. Botella, J. Breton-Lopez, S. Quero, R. M. Baños, A. Garcia-Palacios, I. Zaragoza, and M. Alcaniz, “Treating cockroach phobia using a serious game on a mobile phone and augmented reality exposure: A single case study,” *Computers in Human Behavior*, vol. 27, no. 1, pp. 217–227, 2011.

[102] V. Guillén-Nieto and M. Aleson-Carbonell, “Serious games and learning effectiveness: The case of it's a deal!,” *Computers & Education*, vol. 58, no. 1, pp. 435–448, 2012.

[103] M. Bakhuys Roozeboom, G. Visschedijk, and E. Oprins, “The effectiveness of three serious games measuring generic learning features,” *British Journal of Educational Technology*, 2015.

[104] L. ChanLin, “Formats and prior knowledge on learning in a computer-based lesson,” *Journal of Computer Assisted Learning*, vol. 17, no. 4, pp. 409–419, 2001.

[105] J. Stanley and T. Willlamson, “Knowing how,” *The Journal of Philosophy*, vol. 98, no. 8, pp. 411–444, 2001.

[106] T. Refeng, “Knowing that, knowing how, and knowing to do,” *Frontiers of Philosophy in China*, vol. 6, no. 3, pp. 426–442, 2011.

[107] F. Ganier, C. Hoareau, and J. Tisseau, “Evaluation of procedural learning transfer from a virtual environment to a real situation: a case study on tank maintenance training,” *Ergonomics*, vol. 57, no. 6, pp. 828–843, 2014.

[108] M. Jou and J. Wang, “Investigation of effects of virtual reality environments on learning performance of technical skills,” *Computers in Human Behavior*, vol. 29, no. 2, pp. 433–438, 2013.

[109] R. Källström, H. Hjertberg, and J. Svanvik, “Construct validity of a full procedure, virtual reality, real-time, simulation model for training in transurethral resection of the prostate,” *Journal of endourology*, vol. 24, no. 1, pp. 109–115, 2010.

[110] R. E. Rhodes, J. Kopecky, N. Bos, J. McKneely, A. Gertner, F. Zaromb, A. Perrone, and J. Spitaletta, “Teaching decision making with serious games,” *Games and Culture*, vol. 12, no. 3, pp. 233–251, 2017.

[111] R. M. Hulteen, N. D. Ridgers, T. M. Johnson, R. R. Mellecker, and L. M. Barnett, “Children's movement skills when playing active video games,” *Perceptual and motor skills*, vol. 121, no. 3, pp. 767–790, 2015.

[112] B. J. Adams, F. Margaron, and B. J. Kaplan, “Comparing video games and laparoscopic simulators in the development of laparoscopic skills in surgical residents,” *Journal of surgical education*, vol. 69, no. 6, pp. 714–717, 2012.

[113] D. A. Huffaker and S. L. Calvert, “The new science of learning: Active learning, metacognition, and transfer of knowledge in e-learning applications,” *Journal of Educational Computing Research*, vol. 29, no. 3, pp. 325–334, 2003.

[114] C. Bossard, G. Kermarrec, C. Buche, and J. Tisseau, “Transfer of learning in virtual environments: a new challenge?,” *Virtual Reality*, vol. 12, no. 3, pp. 151–161, 2008.

[115] J. Bertram, J. Moskaliuk, and U. Cress, “Virtual training: Making reality work?,” *Computers in Human Behavior*, vol. 43, pp. 284–292, 2015.

[116] J. Tirp, C. Steingröver, N. Wattie, J. Baker, and J. Schorer, “Virtual realities as optimal learning environments in sport–a transfer study of virtual and real dart throwing,” *Psychological Test and Assessment Modeling*, vol. 57, no. 1, p. 57, 2015.

[117] C. B. de Mello Monteiro, T. Massetti, T. D. da Silva, J. van der Kamp, L. C. de Abreu, C. Leone, and G. J. Savelsbergh, “Transfer of motor learning from virtual to natural environments in individuals with cerebral palsy,” *Research in developmental disabilities*, vol. 35, no. 10, pp. 2430–2437, 2014.

[118] J. Parong, R. E. Mayer, L. Fiorella, A. MacNamara, B. D. Homer, and J. L. Plass, “Learning executive function skills by playing focused video games,” *Contemporary Educational Psychology*, vol. 51, pp. 141–151, 2017.

[119] R. Rosas, M. Nussbaum, P. Cumsille, V. Marianov, M. Correa, P. Flores, V. Grau, F. Lagos, X. López, V. López, *et al.*, “Beyond nintendo: design and assessment of educational video games for first and second grade students,” *Computers & Education*, vol. 40, no. 1, pp. 71–94, 2003.

[120] A. DomíNguez, J. Saenz-De-Navarrete, L. De-Marcos, L. FernáNdez-Sanz, C. PagéS, and J.-J. MartíNez-HerráIz, “Gamifying learning experiences: Practical implications and outcomes,” *Computers & Education*, vol. 63, pp. 380–392, 2013.

[121] C. Beedie, P. Terry, and A. Lane, “Distinctions between emotion and mood,” *Cognition & Emotion*, vol. 19, no. 6, pp. 847–878, 2005.

[122] J. Rottenberg, “Mood and emotion in major depression,” *Current Directions in Psychological Science*, vol. 14, no. 3, pp. 167–170, 2005.

[123] A. M. Lane and P. C. Terry, “The nature of mood: Development of a conceptual model with a focus on depression,” *Journal of applied sport psychology*, vol. 12, no. 1, pp. 16–33, 2000.

[124] D. Zillmann, “Mood management through communication choices,” *American Behavioral Scientist*, vol. 31, no. 3, pp. 327–340, 1988.

[125] J. Breuer and G. Bente, “Why so serious? on the relation of serious games and learning,” *Journal for Computer Game Culture*, vol. 4, pp. 7–24, 2010.

[126] C. M. Hettena and B. L. Ballif, "Effects of mood on learning.," *Journal of Educational Psychology*, vol. 73, no. 4, p. 505, 1981.

[127] R. Opengart, "Emotional intelligence and emotion work: Examining constructs from an interdisciplinary framework," *Human Resource Development Review*, vol. 4, no. 1, pp. 49–62, 2005.

[128] B. Shuck, C. Albornoz, and M. Winberg, "Emotions and their effect on adult learning: A constructivist perspective," in *Proceedings of the Sixth Annual College of Education Research Conference: Urban and International Education Section* (S. M. Nielsen and M. S. Plakhotnik, eds.), (Miami), pp. 108–113), Florida International University, 2007.

[129] J. M. Dirkx, "The power of feelings: Emotion, imagination, and the construction of meaning in adult learning," *New directions for adult and continuing education*, vol. 2001, no. 89, pp. 63–72, 2001.

[130] J. E. Zull, *The art of changing the brain: Enriching teaching by exploring the biology of learning.* Stylus Publishing, LLC., 2002.

[131] B. D. Perry, "Fear and learning: Trauma-related factors in the adult education process," *New Directions for Adult and Continuing Education*, vol. 2006, no. 110, pp. 21–27, 2006.

[132] B. L. Fredrickson and C. Branigan, "Positive emotions broaden the scope of attention and thought-action repertoires," *Cognition & emotion*, vol. 19, no. 3, pp. 313–332, 2005.

[133] S. Brand and K. Opwis, "Effects of mood and problem solving in dyads on transfer," *Swiss journal of psychology*, vol. 66, no. 1, pp. 51–65, 2007.

[134] T. W. Liew and T. Su-Mae, "The effects of positive and negative mood on cognition and motivation in multimedia learning environment," *Journal of Educational Technology & Society*, vol. 19, no. 2, p. 104, 2016.

[135] J. Bertels, C. Demoulin, A. Franco, and A. Destrebecqz, "Side effects of being blue: influence of sad mood on visual statistical learning," *PloS one*, vol. 8, no. 3, p. e59832, 2013.

[136] M. Rinck, U. Glowalla, and K. Schneider, "Mood-congruent and mood-incongruent learning," *Memory & cognition*, vol. 20, no. 1, pp. 29–39, 1992.

[137] C. Dormann and R. Biddle, "Humor and computer games: Play, laugh, and more—a review," *Simulation & gaming*, 2009.

[138] J. Jansz, "The emotional appeal of violent video games for adolescent males," *Communication theory*, vol. 15, no. 3, pp. 219–241, 2005.

[139] E. Brox, L. Fernandez-Luque, T. Tøllefsen, *et al.*, "Healthy gaming–video game design to promote health," *Applied clinical informatics*, vol. 2, no. 2, pp. 128–142, 2011.

[140] A. Mitchell and C. Savill-Smith, *The use of computer and video games for learning: A review of the literature.* Learning and Skills Development Agency, 2004.

[141] Y. Tazawa, A. V. Soukalo, K. Okada, and G. Takada, "Excessive playing of home computer games by children presenting unexplained symptoms," *The Journal of pediatrics*, vol. 130, no. 6, pp. 1010–1011, 1997.

[142] N. Yee, "Motivations for play in online games," *CyberPsychology & behavior*, vol. 9, no. 6, pp. 772–775, 2006.

[143] T. Susi, M. Johannesson, and P. Backlund, "Serious games: An overview," 2007.

[144] F. Fernández-Aranda, S. Jiménez-Murcia, J. J. Santamaría, K. Gunnard, A. Soto, E. Kalapanidas, R. G. Bults, C. Davarakis, T. Ganchev, R. Granero, *et al.*, "Video games as a complementary therapy tool in mental disorders: Playmancer, a european multicentre study," *Journal of Mental Health*, vol. 21, no. 4, pp. 364–374, 2012.

[145] L. Nacke, A. Drachen, and S. Göbel, "Methods for evaluating gameplay experience in a serious gaming context," *International Journal of Computer Science in Sport*, vol. 9, no. 2, pp. 1–12, 2010.

[146] S. Franceschini, S. Gori, M. Ruffino, S. Viola, M. Molteni, and A. Facoetti, "Action video games make dyslexic children read better," *Current Biology*, vol. 23, no. 6, pp. 462–466, 2013.

[147] P. Sweetser and P. Wyeth, "GameFlow: a model for evaluating player enjoyment in games," *Computers in Entertainment (CIE)*, vol. 3, no. 3, pp. 3–3, 2005.

[148] F.-L. Fu, R.-C. Su, and S.-C. Yu, "EGameFlow: A scale to measure learners' enjoyment of e-learning games," *Computers & Education*, vol. 52, no. 1, pp. 101–112, 2009.

[149] N. F. Gould, M. K. Holmes, F. Bryan D, D. A. Luckenbaugh, D. S. Pine, T. D. Gould, N. Burgess, H. K. Manji, and C. A. Zarate, "Performance on a virtual reality spatial memory navigation task in depressed patients," *American Journal of Psychiatry*, vol. 164, no. 3, pp. 516–519, 2007.

[150] S. Ainsworth, "The functions of multiple representations," *Computers & education*, vol. 33, no. 2, pp. 131–152, 1999.

[151] S. Ainsworth, "Deft: A conceptual framework for considering learning with multiple representations," *Learning and instruction*, vol. 16, no. 3, pp. 183–198, 2006.

[152] S. Löhner, W. R. van Joolingen, E. R. Savelsbergh, and B. van Hout-Wolters, "Students' reasoning during modeling in an inquiry learning environment," *Computers in Human Behavior*, vol. 21, no. 3, pp. 441–461, 2005.

[153] K. Stenning, R. Cox, and J. Oberlander, "Contrasting the cognitive effects of graphical and sentential logic teaching: reasoning, representation and individual differences," *Language and Cognitive Processes*, vol. 10, no. 3-4, pp. 333–354, 1995.

[154] W. Schnotz, "Commentary: Towards an integrated view of learning from text and visual displays," *Educational psychology review*, vol. 14, no. 1, pp. 101–120, 2002.

[155] F. Mashhadi and G. Jamalifar, "Second language vocabulary learning through visual and textual representation," *Procedia-Social and Behavioral Sciences*, vol. 192, pp. 298–307, 2015.

[156] I. Tapiero, "The construction and updating of a spatial mental model from text and map: Effect of imagery and anchor," *Multimedia learning: Cognitive and instructional Issues*, pp. 45–57, 2001.

[157] S. Webb and A. C. Chang, "Second language vocabulary learning through extensive reading with audio support: How do frequency and distribution of occurrence affect learning?," *Language Teaching Research*, vol. 19, no. 6, pp. 667–686, 2015.

[158] J. D. de Oliveira Neto, W. D. Huang, and N. C. de Azevedo Melli, "Online learning: audio or text?," *Educational Technology Research and Development*, vol. 63, no. 4, pp. 555–573, 2015.

[159] A. M. Johnson, K. R. Butcher, G. Ozogul, and M. Reisslein, "Learning from abstract and contextualized representations: The effect of verbal guidance," *Computers in Human Behavior*, vol. 29, no. 6, pp. 2239–2247, 2013.

[160] M. G. Katz, S. Kripalani, and B. D. Weiss, "Use of pictorial aids in medication instructions: a review of the literature," *American Journal of Health-System Pharmacy*, vol. 63, no. 23, pp. 2391–2398, 2006.

[161] J. H. Larkin and H. A. Simon, "Why a diagram is (sometimes) worth ten thousand words," *Cognitive science*, vol. 11, no. 1, pp. 65–100, 1987.

[162] S. Ainsworth and A. T. Loizou, "The effects of self-explaining when learning with text or diagrams," *Cognitive science*, vol. 27, no. 4, pp. 669–681, 2003.

[163] A. D. Ritzhaupt and W. A. Kealy, "On the utility of pictorial feedback in computer-based learning environments," *Computers in Human Behavior*, vol. 48, pp. 525–534, 2015.

[164] M. Glaser and S. Schwan, "Explaining pictures: How verbal cues influence processing of pictorial learning material.," *Journal of Educational Psychology*, vol. 107, no. 4, p. 1006, 2015.

[165] J. Stoszkowski and D. Collins, "Communities of practice, social learning and networks: Exploiting the social side of coach development," *Sport, education and society*, vol. 19, no. 6, pp. 773–788, 2014.

[166] M. R. Drake, "Learning to coach in practice-based teacher education: A self-study," *Studying Teacher Education*, vol. 12, no. 3, pp. 244–266, 2016.

[167] R. Gallimore, W. Gilbert, and S. Nater, "Reflective practice and ongoing learning: a coach's 10-year journey," *Reflective Practice*, vol. 15, no. 2, pp. 268–288, 2014.

[168] W. Gilbert, R. Gallimore, and P. Trudel, "A learning community approach to coach development in youth sport," *Journal of coaching education*, vol. 2, no. 2, pp. 3–23, 2009.

[169] D. A. Schön, *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions.* Jossey-Bass, 1987.

[170] A. Smith, "Learning about reflection," *Journal of Advanced Nursing*, vol. 28, no. 4, pp. 891–898, 1998.

[171] D. N. M. Lew and H. G. Schmidt, "Writing to learn: can reflection journals be used to promote self-reflection and learning?," *Higher Education Research & Development*, vol. 30, no. 4, pp. 519–532, 2011.

[172] R. Brown, R. Waring, and S. Donkaewbua, "Incidental vocabulary acquisition from reading, reading-while-listening, and listening to stories," *Reading in a foreign language*, vol. 20, no. 2, p. 136, 2008.

[173] S. Webb and A. C. Chang, "Vocabulary learning through assisted and unassisted repeated reading," *Canadian Modern Language Review*, vol. 68, no. 3, pp. 267–290, 2012.

[174] S. Kalyuga, "When using sound with a text or picture is not beneficial for learning," *Australasian Journal of Educational Technology*, vol. 16, no. 2, 2000.

[175] S. Ainsworth, P. Bibby, and D. Wood, "Examining the effects of different multiple representational systems in learning primary mathematics," *The Journal of the Learning Sciences*, vol. 11, no. 1, pp. 25–61, 2002.

[176] A. Ardila, M. Rosselli, E. Matute, and O. Inozemtseva, "Gender differences in cognitive development.," *Developmental psychology*, vol. 47, no. 4, p. 984, 2011.

[177] W. W. K. Ma and A. H. K. Yuen, "Gender differences of knowledge sharing in online learning environment," in *International Conference on Hybrid Learning*, pp. 116–128, Springer, 2011.

[178] W. Wei, H. Lu, H. Zhao, C. Chen, Q. Dong, and X. Zhou, "Gender differences in children's arithmetic performance are accounted for by gender differences in language abilities," *Psychological science*, vol. 23, no. 3, pp. 320–330, 2012.

[179] M. Kaushanskaya, V. Marian, and J. Yoo, "Gender differences in adult word learning," *Acta psychologica*, vol. 137, no. 1, pp. 24–35, 2011.

[180] S. Severiens and G. Dam, "A multilevel meta-analysis of gender differences in learning orientations," *British Journal of Educational Psychology*, vol. 68, no. 4, pp. 595–608, 1998.

[181] E. A. Wehrwein, H. L. Lujan, and S. E. DiCarlo, "Gender differences in learning style preferences among undergraduate physiology students," *Advances in physiology education*, vol. 31, no. 2, pp. 153–157, 2007.

[182] K. Moll, S. Kunze, N. Neuhoff, J. Bruder, and G. Schulte-Körne, "Specific learning disorder: prevalence and gender differences," *PLoS one*, vol. 9, no. 7, p. e103537, 2014.

[183] E. Diniz, L. da Rosa Piccolo, M. C. P. de Paula Couto, J. F. Salles, and S. Helena Koller, "Influences of developmental contexts and gender differences on school performance of children and adolescents," *Educational Psychology*, vol. 34, no. 7, pp. 787–798, 2014.

[184] E. Barrett and V. Lally, "Gender differences in an on-line learning environment," *Journal of Computer Assisted Learning*, vol. 15, no. 1, pp. 48–60, 1999.

[185] C.-S. Ong and J.-Y. Lai, "Gender differences in perceptions and relationships among dominants of e-learning acceptance," *Computers in human behavior*, vol. 22, no. 5, pp. 816–829, 2006.

[186] G. S. Stump, J. C. Hilpert, J. Husman, W.-t. Chung, and W. Kim, "Collaborative learning in engineering students: Gender and achievement," *Journal of Engineering Education*, vol. 100, no. 3, pp. 475–497, 2011.

[187] R. Y.-Y. Chan, J. Huang, D. Hui, S. Li, and P. Yu, "Gender differences in collaborative learning over online social networks: Epistemological beliefs and behaviors," *Knowledge Management & E-Learning: An International Journal (KM&EL)*, vol. 5, no. 3, pp. 234–250, 2013.

[188] F. R. Prinsen, M. Volman, and J. Terwel, "Gender-related differences in computer-mediated communication and computer-supported collaborative learning," *Journal of Computer Assisted Learning*, vol. 23, no. 5, pp. 393–409, 2007.

[189] Z. Zhan, P. S. Fong, H. Mei, and T. Liang, "Effects of gender grouping on students' group performance, individual achievements and attitudes in computer-supported collaborative learning," *Computers in Human Behavior*, vol. 48, pp. 587–596, 2015.

[190] N. Ding, R. J. Bosker, and E. G. Harskamp, “Exploring gender and gender pairing in the knowledge elaboration processes of students using computer-supported collaborative learning,” *Computers & Education*, vol. 56, no. 2, pp. 325–336, 2011.

[191] E. Coluccia and G. Louse, “Gender differences in spatial orientation: A review,” *Journal of environmental psychology*, vol. 24, no. 3, pp. 329–340, 2004.

[192] D. C. Geary, S. J. Saults, F. Liu, and M. K. Hoard, “Sex differences in spatial cognition, computational fluency, and arithmetical reasoning,” *Journal of Experimental child psychology*, vol. 77, no. 4, pp. 337–353, 2000.

[193] M. Palmiero, R. Nori, C. Rogolino, S. D’amico, and L. Piccardi, “Sex differences in visuospatial and navigational working memory: the role of mood induced by background music,” *Experimental brain research*, vol. 234, no. 8, pp. 2381–2389, 2016.

[194] R. Nori, L. Piccardi, M. Migliori, A. Guidazzoli, F. Frasca, D. De Luca, and F. Giusberti, “The virtual reality walking corsi test,” *Computers in Human Behavior*, vol. 48, pp. 72–77, 2015.

[195] D. Rodríguez-Andrés, M.-C. Juan, M. Méndez-López, E. Pérez-Hernández, and J. Lluch, “Mnemocity task: Assessment of childrens spatial memory using stereoscopy and virtual environments,” *PloS one*, vol. 11, no. 8, p. e0161858, 2016.

[196] S. Walkowiak, T. Foulsham, and A. F. Eardley, “Individual differences and personality correlates of navigational performance in the virtual route learning task,” *Computers in Human Behavior*, vol. 45, pp. 402–410, 2015.

[197] J. Cooper and D. Mackie, “Video games and aggression in children,” *Journal of Applied Social Psychology*, vol. 16, no. 8, pp. 726–744, 1986.

[198] M. J. Fleming, R. Wood, and J. Debra, “Effects of violent versus nonviolent video games on children’s arousal, aggressive mood, and positive mood,” *Journal of Applied Social Psychology*, vol. 31, no. 10, pp. 2047–2071, 2001.

[199] J. E. Lee, P. Xiang, and Z. Gao, “Acute effect of active video games on older children’s mood change,” *Computers in Human Behavior*, vol. 70, pp. 97–103, 2017.

[200] M. Israel, S. Wang, and M. T. Marino, “A multilevel analysis of diverse learners playing life science video games: Interactions between game content, learning disability status, reading proficiency, and gender,” *Journal of Research in Science Teaching*, vol. 53, no. 2, pp. 324–345, 2016.

[201] J. B. Weaver, D. Mays, S. S. Weaver, W. Kannenberg, G. L. Hopkins, D. Eroĝlu, and J. M. Bernhardt, “Health-risk correlates of video-game playing among adults,” *American Journal of Preventive Medicine*, vol. 37, no. 4, pp. 299–305, 2009.

[202] TH Education Unit, “The Introduction of Hajj,” in *Hajj, Umrah and Visits*, pp. 3–21, Lembaga Tabung Haji (TH), Malaysia, 2007.

[203] TH Education Unit, “Makkah al-Mukarramah,” in *Hajj, Umrah and Visits*, pp. 202–236, Lembaga Tabung Haji (TH), Malaysia, 2007.

[204] TH Education Unit, “2nd Week: History of Masjidil Haram,” in *Hajj Basic Course Module*, pp. 9–28, Lembaga Tabung Haji (TH), Malaysia, 2014.

[205] J. Schneider, D. Garatly, M. Srinivasan, S. J. Guy, S. Curtis, S. Cutchin, D. Manocha, M. C. Lin, and A. Rockwood, “Towards a Digital Makkah–Using Immersive 3D Environments to Train and Prepare Pilgrims,” in *International Conference on Digital Media and its Applications in Cultural Heritage (DMACH)*, 2011.

[206] K. Nelson, “Hajj 2016: When is the annual Mecca pilgrimage? Who goes? Is it safe? Everything you need to know.” http://www.independent.co.uk/news/world/middle-east/hajj-2016-date-when-is-it-mecca-who-goes-is-it-safe-islam-muslims-stampede-2015-a7209676.html, September 06, 2016. Independent. Last accessed December 05, 2016.

[207] TH Education Unit, “The Introduction of Umrah,” in *Hajj, Umrah and Visits*, pp. 172–177, Lembaga Tabung Haji (TH), Malaysia, 2007.

[208] TH Education Unit, “3rd Week: Introduction of Hajj and Umrah,” in *Hajj Basic Course Module*, pp. 29–40, Lembaga Tabung Haji (TH), Malaysia, 2014.

[209] A. M. Yasin, F. H. Yusoff, M. A. M. Isa, and N. H. M. Zain, “Avatar implementation in virtual reality environment using situated learning for “sa’i”(muslim hajj ritual),” in *Educational and Information Technology (ICEIT), 2010 International Conference on*, vol. 2, pp. 286–290, IEEE, 2010.

[210] B. A. Al-Naja, “King Abdullah launches SR80 billion Haram expansion project.” http://www.arabnews.com/node/388203, August 20, 2011. Arab News. Last accessed December 07, 2016.

[211] Arab News, “Grand Mosque extension opens for Haj.” http://www.arabnews.com/saudi-arabia/news/635911, September 26, 2014. Last accessed December 07, 2016.

[212] BBC News, “Saudi Arabia: Pilgrim get lost inside Grand Mosque.” http://www.bbc.co.uk/news/blogs-news-from-elsewhere-26070998, February 06, 2014. Last accessed December 07, 2016.

[213] Al-Arabiya English, “Saudi Arabia says Hajj 2016 receives 1.8 million pilgrims.” http://english.alarabiya.net/en/News/middle-east/2016/09/12/Saudi-Arabia-says-Hajj-2016-receives-1-8-million-pilgrims.html, September 12, 2016. Last accessed December 05, 2016.

[214] Saudi Gazette, “Least number of Hajis this year.” http://saudigazette.com.sa/saudi-arabia/least-number-hajis-year/, September 16, 2016. Last accessed December 05, 2016.

[215] A. Al-Rabie, "3.7 million Umrah pilgrims arrive." http://saudigazette.com.sa/saudi-arabia/3-7-million-umrah-pilgrims-arrive/, April 05, 2016. Saudi Gazette. Last accessed December 05, 2016.

[216] TH Education Unit, "Hajj Rukun," in *Hajj, Umrah and Visits*, pp. 22–53, Lembaga Tabung Haji (TH), Malaysia, 2007.

[217] TH Education Unit, "Umrah Rukun," in *Hajj, Umrah and Visits*, pp. 178–184, Lembaga Tabung Haji (TH), Malaysia, 2007.

[218] TH Education Unit, "Hajj Wajib," in *Hajj, Umrah and Visits*, pp. 54–91, Lembaga Tabung Haji (TH), Malaysia, 2007.

[219] TH Education Unit, "Umrah Wajib," in *Hajj, Umrah and Visits*, pp. 185–201, Lembaga Tabung Haji (TH), Malaysia, 2007.

[220] TH Education Unit, "6th Week: Sa'ie, Shaving or Cutting Hair and Maintaining the Sequence," in *Hajj Basic Course Module*, pp. 71–88, Lembaga Tabung Haji (TH), Malaysia, 2014.

[221] TH Education Unit, "Women in Hajj and Umrah," in *Hajj, Umrah and Visits*, pp. 143–151, Lembaga Tabung Haji (TH), Malaysia, 2007.

[222] Arab News, "Mataf bridge removed." http://www.arabnews.com/news/mataf-bridge-removed, May 14, 2016. Last accessed December 07, 2016.

[223] TH Education Unit, "Hajj: Guidance Services." http://www.tabunghaji.gov.my/guidance, 2015. Last accessed January 19, 2015.

[224] M. S. M. Rahim, A. Z. A. Fata, A. H. Basori, A. S. Rosman, T. J. Nizar, and F. W. M. Yusof, "Development of 3d tawaf simulation for hajj training application using virtual environment," in *International Visual Informatics Conference*, pp. 67–76, Springer, 2011.

[225] M. F. Yusoff, A. N. Zulkifli, and N. F. F. Mohamed, "The evaluation of v-hajj: A courseware for hajj learning procedures," in *Knowledge Management International Conference (KMICe) 2012, 4—6 July 2012, Johor Bahru, Malaysia*, pp. 599–604, 2012.

[226] M. F. Yusoff, A. N. Zulkifli, and N. F. F. Mohamed, "Virtual hajj (v-hajj)—adaptation of persuasive design in virtual environment (ve) and multimedia integrated approach learning courseware methodology," in *Open Systems (ICOS), 2011 IEEE Conference on*, pp. 250–255, IEEE, 2011.

[227] N. Rahim, N. A. Hamid, W. M. W. Isa, S. D. M. Satar, and A. Rozaimee, "A survey on components of virtual'umrah application," *The International Journal of Multimedia & Its Applications*, vol. 5, no. 5, p. 17, 2013.

[228] Ministry of Hajj, Kingdom of Saudi Arabia, "Information about Hajj." http://hajj.al-islam.com, 2015. Last accessed January 23, 2015.

[229] S. Sarmady, F. Haron, and A. Z. Talib, "Agent-based simulation of crowd at the tawaf area," in *Proceedings of the National Seminar on Hajj Best Practices Through Advances in Science & Technology, 28–30 May 2007, Universiti Sains Malaysia,Pulau Pinang*, pp. 129–136, 2007.

[230] R. Narain, A. Golas, S. Curtis, and M. C. Lin, "Aggregate dynamics for dense crowd simulation," *ACM Transactions on Graphics (TOG)*, vol. 28, pp. 122:1–122:8, Dec. 2009.

[231] S. Curtis, S. J. Guy, B. Zafar, and D. Manocha, "Virtual tawaf: A case study in simulating the behavior of dense, heterogeneous crowds," in *Computer Vision Workshops (ICCV Workshops), 2011 IEEE International Conference On*, pp. 128–135, IEEE, 2011.

[232] S. Curtis, S. J. Guy, B. Zafar, and D. Manocha, "Virtual tawaf: a velocity-space-based solution for simulating heterogeneous behavior in dense crowds," in *Modeling, Simulation and Visual Analysis of Crowds*, pp. 181–209, Springer, 2013.

[233] A. A. Ziden and M. F. A. Rahman, "The effectiveness of web-based multimedia applications simulation in teaching and learning.," *Online Submission*, vol. 6, no. 2, pp. 211–222, 2013.

[234] A. M. Yasin, Z. Darleena, and M. A. M. Isa, "Avatar implementation in virtual reality environment using situated learning for "tawaf"," *Procedia-Social and Behavioral Sciences*, vol. 67, pp. 73–80, 2012.

[235] D. Anguelov, C. Dulong, D. Filip, C. Frueh, S. Lafon, R. Lyon, A. Ogale, L. Vincent, and J. Weaver, "Google street view: Capturing the world at street level," *Computer*, vol. 43, no. 6, pp. 32–38, 2010.

[236] M. Hegarty, A. E. Richardson, D. R. Montello, K. Lovelace, and I. Subbiah, "Development of a self-report measure of environmental spatial ability," *Intelligence*, vol. 30, no. 5, pp. 425–447, 2002.

[237] B. G. Witmer and M. J. Singer, "Measuring presence in virtual environments: A presence questionnaire," *Presence: Teleoperators and virtual environments*, vol. 7, no. 3, pp. 225–240, 1998.

[238] J. D. Mayer and Y. Gaschke, "Brief mood introspection scale (bmis)," *Psychology*, vol. 21, no. 3, pp. 237–244, 1995.

[239] J. D. Mayer and Y. N. Gaschke, "The experience and meta-experience of mood.," *Journal of personality and social psychology*, vol. 55, no. 1, p. 102, 1988.

[240] E. Suma, S. Finkelstein, M. Reid, S. Babu, A. Ulinski, and L. F. Hodges, "Evaluation of the cognitive effects of travel technique in complex real and virtual environments," *IEEE Transactions on Visualization and Computer Graphics*, vol. 16, no. 4, pp. 690–702, 2010.

[241] O. J. P. dit Dariel, T. Raby, F. Ravaut, and M. Rothan-Tondeur, "Developing the serious games potential in nursing education," *Nurse education today*, vol. 33, no. 12, pp. 1569–1575, 2013.

[242] J. Sánchez and R. Olivares, "Problem solving and collaboration using mobile serious games," *Computers & Education*, vol. 57, no. 3, pp. 1943–1952, 2011.

[243] J. Earp, M. Ott, M. Popescu, M. Romero, and M. Usart, "Supporting human capital development with serious games: An analysis of three experiences," *Computers in Human Behavior*, vol. 30, pp. 715–720, 2014.

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

Appendix A

Study 1: Navigation Instructions

The following figures present instructions that were used in the navigation task in Study 1 (Section 4.4, Chapter 4).

NAVIGATION TASK: STUDY 1 (VE_T)
Finding the Destination by Following a Sequence of Instructions

Navigation Task – Instructions for Participant

Please follow each instruction accordingly to reach your destination.

Start Point : 30 Regent Street
Destination : Universal Computers

1. Now you are on Regent Street and are facing Portobello.
2. You head on Regent Street toward Portobello.
3. Then, you slight left onto Portobello.
4. Immediately, you slight right onto St George's Terrace.
5. Now you head on toward Brook Hill/B6539.
6. When you reach Brook Hill/B6539, you turn left and head on.
7. When you see St George's Close, you turn right onto it.
8. Now you head on St George’s Close until you reach the blue line.
9. You look left to see the destination, Universal Computers.
10. Now please notify **Experimenter** that you are done. Thank you.

Figure A.1: Instructions for participants in the virtual environment group who used text on paper

NAVIGATION TASK: STUDY 1 (GS_T)
Finding the Destination by Following a Sequence of Instructions

Navigation Task – Instructions for Participant

Please follow each instruction accordingly to reach your destination.

Start Point : 1 Newcastle Street
Destination : Flame Hardeners Limited

1. Now you are on Newcastle Street and are facing Broad Lane/B6539.
2. You head on Newcastle Street toward Broad Lane/B6539.
3. Then, you turn right onto Broad Lane/B6539 and head on.
4. When you see Rockingham Street, you turn right onto it.
5. Now, you head on toward Boden Lane (Boden Lane is between Sheffield Window Centre and Silver Steel House).
6. When you see Boden Lane, you turn left onto it and head on.
7. When you see Bailey Lane, you turn right onto it.
8. You head on Bailey Lane until the front of destination, Flame Hardeners Limited.
9. You look left to see the destination, Flame Hardeners Limited.
10. Now please notify **Experimenter** that you are done. Thank you.

Figure A.2: Instructions for participants in the Google Street View group who used text on paper

NAVIGATION TASK: STUDY 1 (VE_P)
Finding the Destination by Following a Sequence of Instructions

Details of Navigation Task

Start Point : 30 Regent Street
Destination : Universal Computers

A Set of Conversation for Instructor

Hello! I am **Y**. I am going to instruct you how to find the destination which is Universal Computers from the start point, 30 Regent Street.

1. Now you are on Regent Street and are facing Portobello.
2. You head on Regent Street toward Portobello.
3. Then, you slight left onto Portobello.
4. Immediately, you slight right onto St George's Terrace.
5. Now you head on toward Brook Hill/B6539.
6. When you reach Brook Hill/B6539, you turn left and head on.
7. When you see St George's Close, you turn right onto it.
8. Now you head on St George's Close until you reach the blue line.
9. You look left to see the destination, Universal Computers.
10. Now please notify **Experimenter** that you are done. Thank you and good bye.

Figure A.3: Instructions for the phone instructor in the virtual environment

NAVIGATION TASK: STUDY 1 (GS_P)
Finding the Destination by Following a Sequence of Instructions

Details of Navigation Task

Start Point	:	1 Newcastle Street
Destination	:	Flame Hardeners Limited

A Set of Conversation for Instructor

Hello! I am **Y**. I am going to instruct you how to find the destination which is Flame Hardeners Limited from the start point, 1 Newcastle Street.

1. Now you are on Newcastle Street and are facing Broad Lane/B6539.
2. You head on Newcastle Street toward Broad Lane/B6539.
3. Then, you turn right onto Broad Lane/B6539 and head on.
4. When you see Rockingham Street, you turn right onto it.
5. Now, you head on toward Boden Lane (Boden Lane is between Sheffield Window Centre and Silver Steel House).
6. When you see Boden Lane, you turn left onto it and head on.
7. When you see Bailey Lane, you turn right onto it.
8. You head on Bailey Lane until the front of destination, Flame Hardeners Limited.
9. You look left to see the destination, Flame Hardeners Limited.
10. Now please notify **Experimenter** that you are done. Thank you and good bye.

Figure A.4: Instructions for the phone instructor in the Google Street View

NAVIGATION TASK: STUDY 1 (VE_C)
Finding the Destination by Following a Sequence of Instructions

Details of Navigation Task

Start Point	:	30 Regent Street
Destination	:	Universal Computers

A Set of Conversation for Instructor

Hello! I am **Z**. I am going to instruct you how to find the destination which is Universal Computers from the start point, 30 Regent Street.

1. Now you are on Regent Street and are facing Portobello.
2. You head on Regent Street toward Portobello.
3. Then, you slight left onto Portobello.
4. Immediately, you slight right onto St George's Terrace.
5. Now you head on toward Brook Hill/B6539.
6. When you reach Brook Hill/B6539, you turn left and head on.
7. When you see St George's Close, you turn right onto it.
8. Now you head on St George's Close until you reach the blue line.
9. You look left to see the destination, Universal Computers.
10. Now you are done. Thank you.

Figure A.5: Instructions for the instructor (direct companion) in the virtual environment

NAVIGATION TASK: STUDY 1 (GS_C)

Finding the Destination by Following a Sequence of Instructions

Details of Navigation Task

Start Point	:	1 Newcastle Street
Destination	:	Flame Hardeners Limited

A Set of Conversation for Instructor

Hello! I am **Z**. I am going to instruct you how to find the destination which is Flame Hardeners Limited from the start point, 1 Newcastle Street.

1. Now you are on Newcastle Street and are facing Broad Lane/B6539.
2. You head on Newcastle Street toward Broad Lane/B6539.
3. Then, you turn right onto Broad Lane/B6539 and head on.
4. When you see Rockingham Street, you turn right onto it.
5. Now, you head on toward Boden Lane (Boden Lane is between Sheffield Window Centre and Silver Steel House).
6. When you see Boden Lane, you turn left onto it and head on.
7. When you see Bailey Lane, you turn right onto it.
8. You head on Bailey Lane until the front of destination, Flame Hardeners Limited.
9. You look left to see the destination, Flame Hardeners Limited.
10. Now you are done. Thank you.

Figure A.6: Instructions for the instructor (direct companion) in the Google Street View

Appendix B

Study 1: Poor Navigation

Below is the full analysis of the poor participants' performance according to Table 4.17 (Chapter 4).

Participant 1
One woman aged around 25-34 years old, did not complete the navigation in the VE, nor in the GS, as she was unable to find the destination although 10 minutes was allocated. In particular, she did not have a driving licence; she never used a SatNav system, although she reported to consider herself as having good spatial and navigational abilities and also a good immersive tendency. The comment section reported she liked to navigate in the GS more than VE; however, in the GS navigation task, she could not see the name of the building (destination) even though she had reached the right street.

In the spatial and navigational abilities test, she answered some items in a different manner from average as below: 1) she disagreed that her "sense of direction" was very good while most participants agreed, 2) she disagreed that she was very good at following a sequence of instructions while most participants agreed, and 3) she disagreed that she tried to remember details of the landscape (objects) when travelling in a new area while most participants agreed.

She also answered some items differently from average in the immersive tendency questionnaire as follows: 1) she could not easily switch her attention from the task in which she was currently involved to a new task while most participants could easily switch, 2) she did not concentrate well on enjoyable activities while most participants concentrated very well, and 3) she rarely became so involved in doing something that she lost all track of time while most participants frequently became so involved.

In the experiment, she was assigned to do the navigation task in the VE first, and followed by GS. To navigate in the VE, she was asked to read the instructions on the paper, whereas in the GS, she was instructed by the phone instructor. As observed in the video of VE navigation, she frequently stopped for a long time during navigation, as if she needed more time to read and understand the instructions given on the paper. In the background information, it was shown that her first language was not English. She was also unlikely to navigate on the road, instead of in the garden and construction area, where she missed a few important landmarks. She was in the correct direction after passing the construction area, but when she missed the signpost of Brook Hill/B6539, she then lost the direction and decided to move back to previous streets, so losing time. In contrast to the VE navigation, in the GS, she managed to arrive at the final road, where the destination was located. However, she still could not arrive at the destination within 10 minutes. As shown in the video, she frequently moved back without turning, as in the reverse mode on cars. She finally was so close to the destination. However, she started losing the correct direction when she missed the destination on her left.

Participant 2

One woman aged around 18-24 years old, navigated well in the VE and GS, however, performed poorly in both RW navigations. For the GS destination in the RW, she successfully reached it, but she took a different route. In her navigation to the VE destination in the RW, she gave up to continue the task after 8 minutes and 27 seconds. In the comment section, she mentioned that although the experiment was interesting such as the VE was real, she was still confused to choose the right paths when navigating in the RW.

According to her spatial and navigational abilities test, she scored lower than the average participant. Also, she answered some items in a different manner from average as follows: 1) she agreed that she had a poor memory for where she left things while most participants disagreed, and 2) she disagreed that she tried to remember details of the landscape (objects) when travelling in a new area while most participants agreed. These were proved by her comments claiming that she felt difficult to recognise and detect landmarks when performing the same task in the RW.

She reported, in the immersive tendency test, to consider herself as having a good tendency. However, she answered some items differently from average, for instance, 1) she could not easily switch her attention from the task in which she was currently involved to a new task while most participants could easily switch, and 2) she frequently avoided carnival and fairground rides because they were too scary while most participants rarely avoided.

In the experiment, she firstly worked with the GS and then, in the VE. In the GS, she was instructed by the companion beside her, whereas in the VE, she was instructed by the phone instructor. Although she navigated well in these two environments, she performed the similar task poorly in the RW navigations, as shown in the route tracked from RunKeeper. When finding the GS destination in the RW, she started losing the correct direction when she missed turning left onto Boden Ln, instead of heading up on Rockingham St, although she managed to reach the destination at the end. By contrast, for the VE destination in the RW, she gave up in the middle of navigation; indicating that her RW navigation to the VE destination was unsuccessful. She, as shown in the RunKeeper data, started to lose the direction when she turned right onto Portobello, although she had to turn left onto it slightly.

Participant 3
One woman aged around 25-34 years old, successfully reached the destination in the VE, however, in the GS, she stopped navigating after 4 minutes and 13 seconds as she gave up, showing that her navigation was unsuccessful. In the comment section, she mentioned that VE was more compelling than GS. She also took 7 minutes and 54 seconds to navigate to the VE destination in the RW that was 4 minutes and 34 seconds more than the average time.

As reported in the spatial and navigational abilities test, she considered herself as having low abilities. In this test, she scored some items in a different manner from average such as 1) she agreed that she had a poor memory for where she left things while most participants disagreed, 2) she disagreed that her "sense of direction" was very good while most participants agreed, and 3) she disagreed that she tried to remember details of the landscape (objects) when travelling in a new area while most participants agreed. These were confirmed by her comments reporting that when navigating, she usually relied on people to guide her and she was likely to ignore the surrounding area, she, therefore, was unable to remember the landmarks.

She reported, in her immersive tendency test, to find herself as having a good tendency. She frequently avoided carnival and fairground rides because they were too scary while most participants rarely avoided.

In the experiment, she did the navigation in the GS first by reading the instructions on the paper. As observed in the GS navigation video, from the starting point (Newcastle St), she navigated well toward Broad Ln/B6539. However, after 4 minutes and 13 seconds navigating in the GS, she suddenly stopped and notified the experimenter that she just gave up the navigation. The video recording shows that as she missed Rockingham St on her right, she then was uncertain where to head to; making her gave up the navigation. She then navigated in the VE, where was instructed by the companion beside her. In this environment, however, she managed to reach the destination within given time (10 minutes).

Participant 4
One woman aged around 25-34 years old, successfully reached the destination in the VE although she took 5 minutes and 7 seconds which was 2 minutes and 15 seconds more than the average time. Interestingly, she just took 2 minutes and 56 seconds to reach the VE destination in the RW. However, in the GS, she did not reach the destination although 10 minutes was allocated. The comment section reported that she found the navigation in the GS was difficult, it, therefore, turned off her motivation to carry out the task successfully.

She never used a SatNav system and reported to have low spatial and navigational abilities. Also, she answered some items in a different manner from average as below: 1) she agreed that she did confuse right and left much while most participants disagreed, 2) she disagreed that her "sense of direction" was very good while most participants agreed, and 3) she agreed that she very easily got lost in an unfamiliar area while most participants disagreed.

Also, she considered herself as having a low immersive tendency. In this test, she answered some items differently from average participant, for instance, 1) she could not easily switch her attention from the task in which she was currently involved to a new task while most participants could easily switch, 2) she did not concentrate well on enjoyable activities while most participants concentrated very well, 3) she frequently avoided carnival and fairground rides because they were too scary while most participants rarely avoided, and 4) she rarely became so involved in doing something that she lost all track of time while most participants frequently became so involved. Also, she reported that she dwelled many personal problems in the last 48 hours before the experiment began.

In the experiment, she was assigned to do in the VE first, followed by GS. In the VE, she used the instructions on the paper to navigate to the destination, whereas in the GS, she was instructed by phone instructor. She finished the navigation in the VE, although she took more than the average time. However, in the GS, she did not complete the task although 10 minutes were allocated. As observed in the video, she started losing the direction when she missed Rockingham St, although she kept navigating on Broad Ln/B6539. She also stopped few times and then she looked round as if she was talking to phone instructor to ask more information and try matching it with her surroundings.

Participant 5

One woman aged around 25-34 years old, navigated well in the VE. She also took less than the average time to reach the VE destination in the RW. However, after 10 minutes was allocated to navigate in the GS, she still could not find the destination.

As reported in the spatial and navigational abilities test, she considered herself as having good abilities. Nevertheless, she agreed that she did confuse right and left a lot while most participants disagreed.

She also reported having a good immersive tendency. However, she mentioned that she had dwelled on many personal problems in the last 48 hours before the experiment began. She, in the comment section, reported that she enjoyed doing the experiment although she felt quite upset as she could not reach the destination in the GS. This comment was proved by her overall mood after the GS navigation task which was unpleasant.

In the experiment, she was assigned to do the navigation task in the VE first, and followed by GS. She, in the VE, was instructed by the companion beside her, where she successfully arrived at the destination. In the GS, she read the instructions on the paper to carry out the task; however, she did not complete it within the time given (10 minutes). As observed in the navigation video, although she kept moving on Rockingham St, she could not spot the location of Boden Ln, so this was the reason she lost the direction in the GS navigation. In this video too, it shows that she mixed the method of moving back to the previous point, in which sometimes she moved back without turning, as in the reverse mode on cars and sometimes, she turned first before moving back to the previous street.

Participant 6
A man who aged around 25-34 years old, navigated well in the VE. He also successfully reached the VE destination in the RW. However, he could not find the destination in the GS although 10 minutes was allocated. In the comment section, he stated that navigation in the VE was better than navigation in the GS.

Interestingly, he used a SatNav system once a week and reported to consider himself as having very good spatial and navigational abilities such as he did not confuse right and left much.

Besides, he considered himself to have a good immersive tendency.

In the experiment, he did the navigation task in the VE and then, in the GS. He managed to reach the destination in the VE, as he was instructed by the companion beside him. In the GS, he used instructions on the paper to carry out the task. However, he did not complete within the time given (10 minutes). The video recording shows that he missed the destination, Flame Hardeners Limited on his left, where he started losing the correct direction. Also, he stopped for a long time few times during his navigation, as if he needed time to read and understand the instructions written on the paper.

Participant 7
One woman aged around 25-34 years old, navigated well in the VE. She also successfully reached the VE destination in the RW. Although 10 minutes was allocated, she could not find the destination in the GS. In the comment section, she mentioned that she liked to navigate in the VE more than GS because it was easy to navigate and to recall the information.

She used a SatNav system once a week. She also reported to consider herself as having very good spatial and navigational abilities such as she did not confuse right and left much, her "sense of direction" was very good and she did not very easily get lost in an unfamiliar area. Also, she considered herself to have a good immersive tendency.

However, the comment section reported that she was quite tired on the experiment day. Thus she could not give full attention to the tasks given. This comment was confirmed by her moods at the beginning of experiment which tired, fed up and in all, unpleasant.

In the experiment, she was assigned to do the navigation task in the GS, followed by VE. In the VE, she was instructed by the companion beside her. In the GS, she read the instructions on the paper. She finished her navigation in the VE; however, she did not complete the task in the GS although 10 minutes were given to her. As seen in the video, she missed Rockingham St first, where she spent much time on a different route before coming back to the assigned route. She then missed Boden Ln on her left, where she again started losing the correct direction.

Participant 8

One woman aged around 18-24 years old, navigated quite well in the VE and GS. In fact, she took less than the average time. However, she took more time to arrive at both destinations in the RW. Badly, she took the wrong route to reach the GS destination in the RW. In the comment section, she reported that navigation in the VE was much easier as only necessary information was simulated. By contrast, GS provided much information to remember; she thus was unable to recall the right paths when navigating to the GS destination in the RW.

Although she described herself as having good spatial and navigational abilities, she answered some items in a different manner from average as following: 1) she agreed that she did confuse right and left much while most participants disagreed, and 2) she agreed that she very easily got lost in an unfamiliar area while most participants disagreed.

Also, she believed that she had a good immersive tendency. However, she reported that she dwelled many personal problems in the last 48 hours before the experiment began.

In the experiment, she firstly did in the VE and then, in the GS. In the VE, she was instructed by the phone instructor, whereas in the GS, she was instructed by the companion beside her. Although she navigated quite well in these two environments, the data from RunKeeper shows that she performed poorly in the RW navigation, in particular, navigation to the GS destination in the RW. As reported in the RunKeeper data, she started losing the correct direction when she missed turning right onto Rockingham St, instead of heading down toward Bailey St, although she managed to reach the destination at the end.

Appendix C

Study 2: Sa'ie Quiz

The following questions are the questions of Sa'ie quiz in Study 2 (Section 5.3.3.3, Chapter 5). The questions in the *italic* format are the extended questions.

1. What is Sa'ie?

   (a) Travelling from Safa hill to Marwah hill by following its Condition
   (b) Travelling from Marwah hill to Safa hill by following its Condition and Sunnah
   (c) Travelling back and forth between Safa hill and Marwah hill by following its Condition
   (d) Travelling back and forth between Safa hill and Marwah hill by following its Condition and Sunnah

2. Before Sa'ie, what are the Conditions pilgrims must do?

   (a) Perform Tawaf
   (b) Be in the state of ritual ablution
   (c) Make the intention of doing Sa'ie
   (d) Put the upper sheet of Ihram garments on the left shoulder which takes it through right armpit

      i. a and b
      ii. a and c
      iii. b and d
      iv. c and d

3. Where is the start of Sa'ie?

   (a) Safa hill
   (b) Marwah hill

4. *Why did you choose the answer of Question 3?*____________________

5. How many rounds must pilgrims do to complete Sa'ie?
   (a) Five
   (b) Six
   (c) Seven
   (d) Eight
6. Is Sa'ie valid if pilgrims just reach the foot of Safa hill and Marwah hill?
   (a) Yes
   (b) No
7. Which is the following is Option(s) of Sa'ie?
   (a) Complete all rounds
   (b) Be persistent in completing all rounds
   (c) Go beside the hills of Safa and Marwah
   (d) Cover the lane between Safa and Marwah
8. Which are the following actions are Options for men only?
   (a) Perform Tawaf
   (b) Walk quickly in the green lights area
   (c) Go over the hills of Safa and Marwah
   (d) Put the upper sheet of Ihram garments on the left shoulder which takes it through right armpit, in each round
      i. a, b and c
      ii. a, c and d
      iii. a, b and d
      iv. b, c and d
9. Which is the following is not Option(s) of Sa'ie?
   (a) Be in the state of ritual ablution
   (b) Cover the lane between Safa and Marwah
   (c) Be persistent in completing all rounds
   (d) While facing Kaabah, make a prayer to God and say Takbir ("God is the greatest")
10. Can pilgrims perform Sa'ie by riding (not by foot)?
   (a) Yes
   (b) No
11. *Why did you choose the answer of Question 10?*____________________

Appendix D

Study 2: Drawings of Landmark Placement

Below is the full description of the drawings in landmark placement task (see Section 5.5.6.6, Chapter 5).

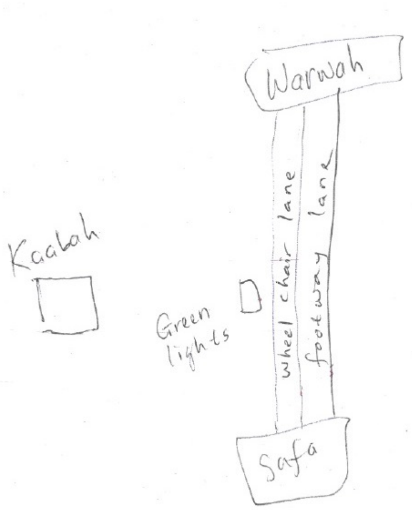
Figure D.1a shows that Safa hill was located at the bottom and Marwah hill at the top of the paper. The drawing was same as in the floor plan presented in the PPT (Figure D.1b). Thirteen participants drew this figure in the Paper 1, in which almost all (12 - 92.31%) learned from PPT. In the Paper 2, the total number dropped to 11 participants, in which also the majority (10 - 90.91%) learned from the PPT.

In the second drawing (Figure D.2), participants positioned Marwah hill on the left and Safa hill on the right of the paper. Interestingly, all participants (100%) who drew this figure in the Paper 1 or even in the Paper 2 learned Sa'ie from the SG. In the Paper 1, 6 participants drew it; however, the number declined to 4 participants in the Paper 2.

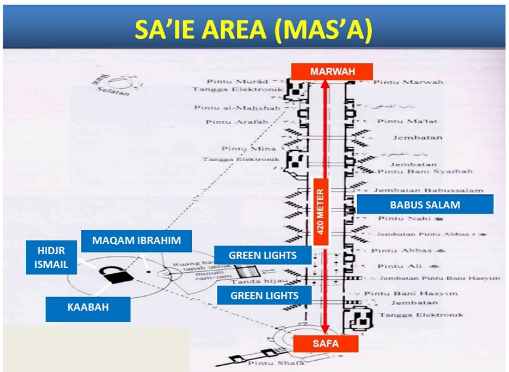
Figure D.3 is just opposite the drawing in Figure D.2, in which participants positioned Marwah hill on the right and Safa hill on the left of the paper. For this drawing, interestingly, participants who drew it were mixed, some of them learned from the SG, and some learned from the PPT. The trend was similar in both Paper 1 and 2. In the Paper 1, 11 participants drew this figure. The number, however, rose in the Paper 2, from 11 to 16 participants.

The drawing in Figure D.4 is so interesting, which Safa hill was located in the south-west, and Marwah hill was located in the north-east of the paper. In the Paper 1 and 2, it was drawn by the same participant (1 participant only) who learned Sa'ie from the SG.

Figure D.5 presents the opposite drawing of Figure D.1a, where Safa hill was located at the top and Marwah hill at the bottom of the paper. However, it was drawn in the Paper 1 only by a participant.



(a) Participants' drawing



(b) The same figure in PPT

Figure D.1: Drawing 1 of landmarks placement

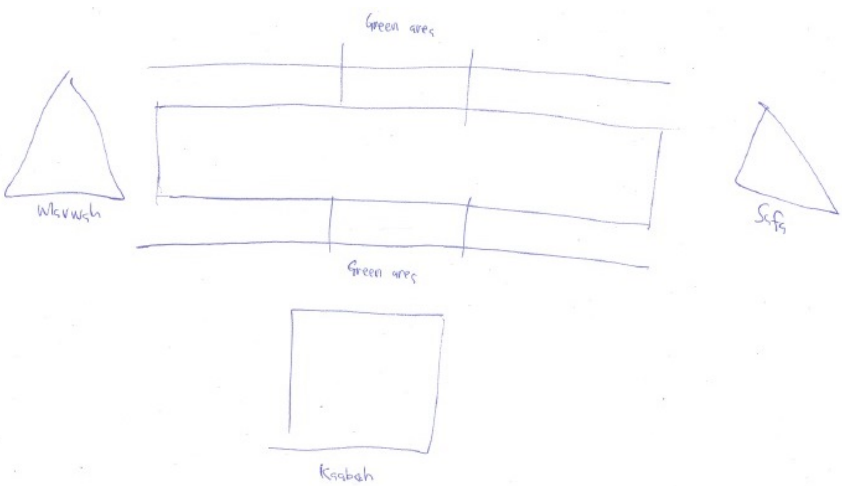


Figure D.2: Drawing 2 of landmarks placement

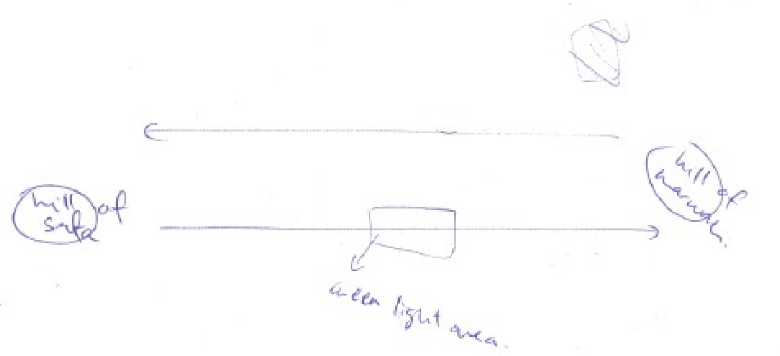


Figure D.3: Drawing 3 of landmarks placement

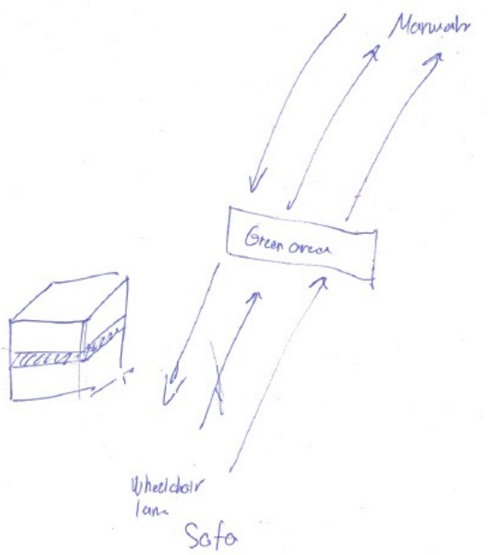


Figure D.4: Drawing 4 of landmarks placement

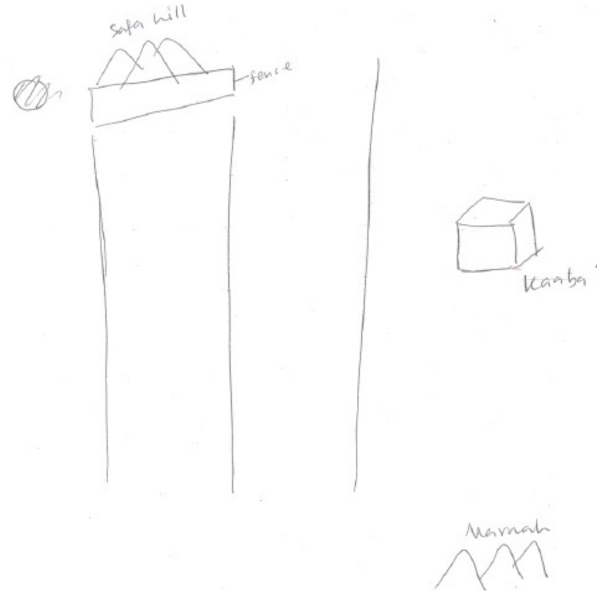


Figure D.5: Drawing 5 of landmarks placement

Appendix E

Study 2: Drawings of Route Recognition

Below is the full description of the drawings in route recognition task (see Section 5.5.6.6, Chapter 5).

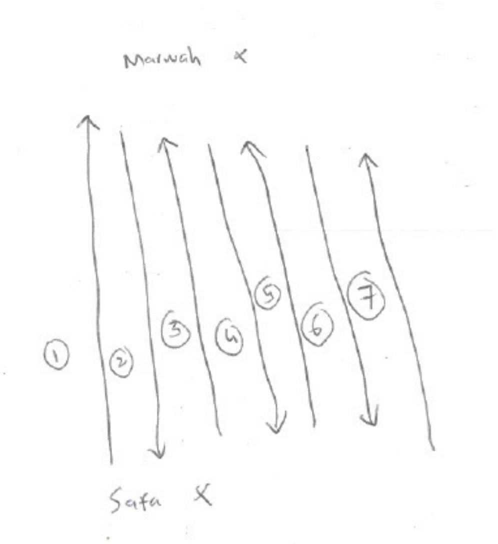
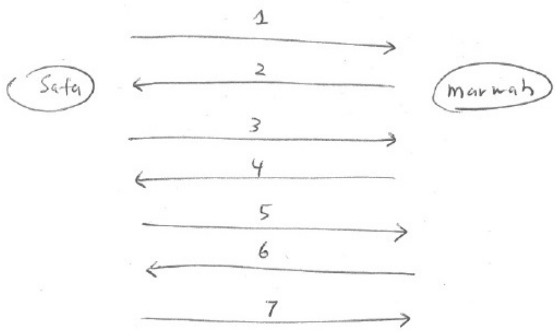
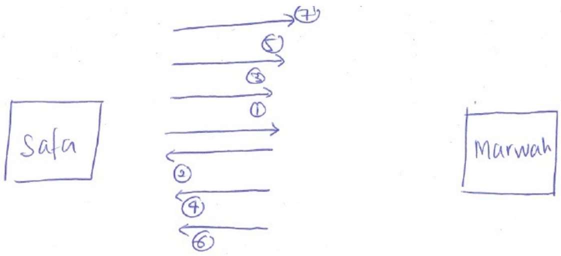


Figure E.1: Drawing 1 of route recognition

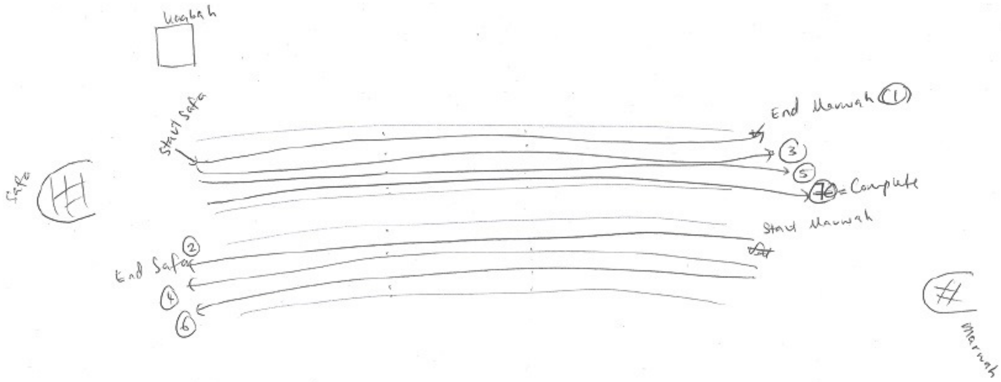
Figure E.1 shows that Safa hill was positioned at the bottom and Marwah hill at the top of the paper. The seven rounds were drawn in straight lines and numbered from left to right. In the Paper 1, 6 participants drew this figure, in which almost (5 - 83.33%) learned from the PPT. However, only 2 participants drew it in the Paper 2 and both participants also learned from the PPT.



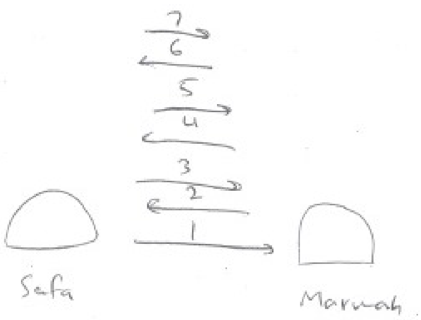
(a)



(b)



(c)



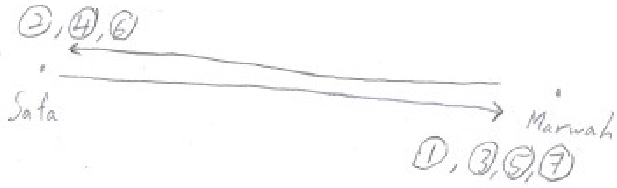
(d)

Figure E.2: Drawing 2 - 5 of route recognition

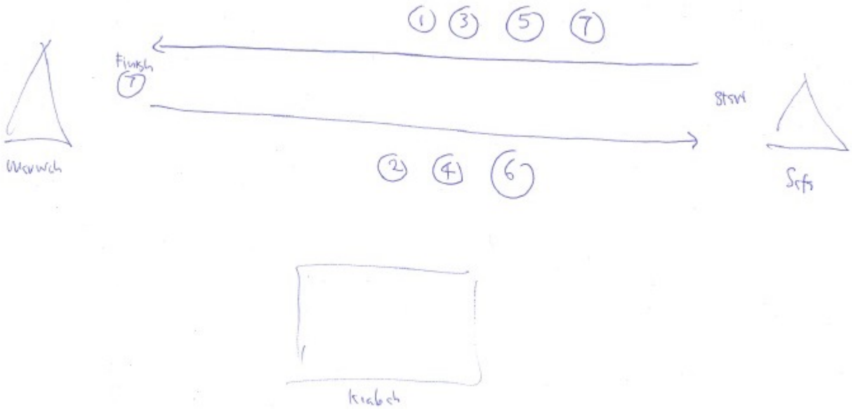
There are four drawings in Figure E.2, which is same regarding straight lines representing the rounds, and location of the hills. Safa hill was located on the left whereas Marwah hill was on the right of the paper. However, the seven rounds were drawn and numbered differently. For Figure E.2a, 6 participants drew it in the Paper 1. Of these, only 4 drew the same figure in the Paper 2. For the next drawings (Figure E.2b - E.2d), each drawing was drawn by 1 participant only. They also repeated it in the Paper 2.

Figure E.3 shows that all three drawings had two rounds only. However, the rounds were numbered properly to indicate the rounds from Safa hill to Marwah hill, and vice versa, except the drawing in Figure E.3c. The location of Safa and Marwah hill was different in these three drawings. Interestingly, these three drawings were drawn by the SG participants only. For Figure E.3a, 3 participants drew it in the Paper 1 and the number reduced to 2 in Paper 2, with 1 of these 2 participants who described the route in text only in the Paper 1. The same pattern was observed for Figure E.3b, however, the participant who described the route in text only in the Paper 1, included an extended text description of his drawing of the Paper 2 (Figure E.4). The final drawing was drawn by 2 participants, and they drew the same figure in the Paper 2.

The curved lines indicating the rounds were drawn in Figure E.5. The difference between the two drawings is the position of the hills. In Figure E.5a, Marwah hill was located on the right, and Safa hill was on the left. While in Figure E.5b, Marwah hill was located at the top and Safa hill was at the bottom of the paper. For Figure E.5a, all participants who drew it learned from the SG, in which 1 participant drew it in the Paper 1, and 2 participants drew it in the Paper 2. In contrast, all participants who drew the drawing in Figure E.5b learned from the PPT. In the Paper 1, it was drawn by 2 participants, and the number declined to 1 participant in the Paper 2.



(a)



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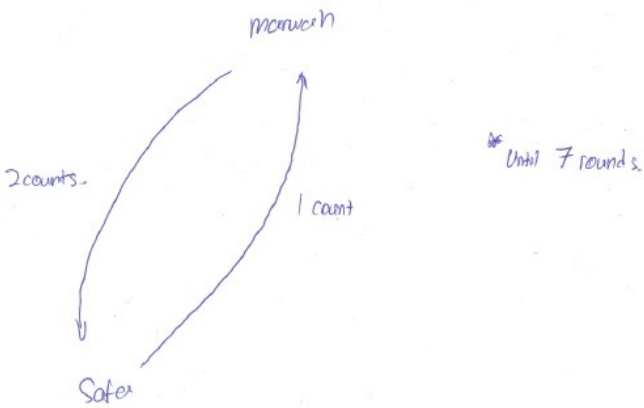


(c)

Figure E.3: Drawing 6 - 8 of route recognition

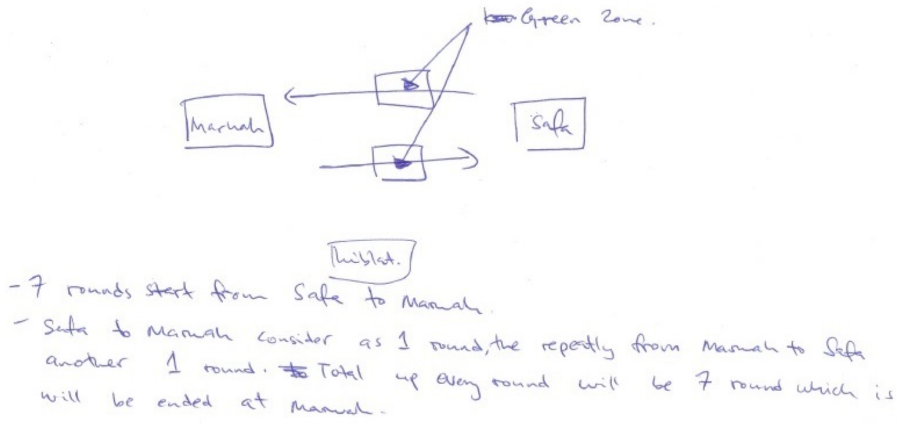
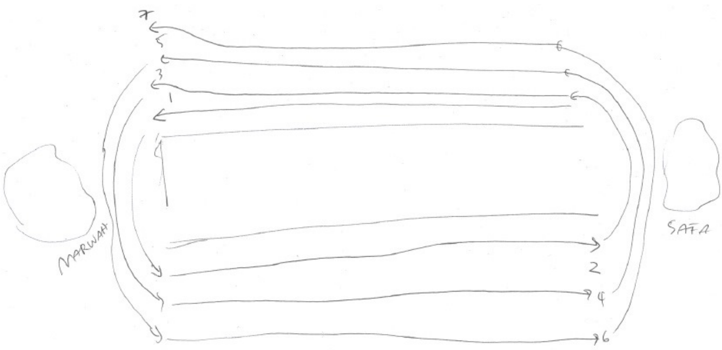
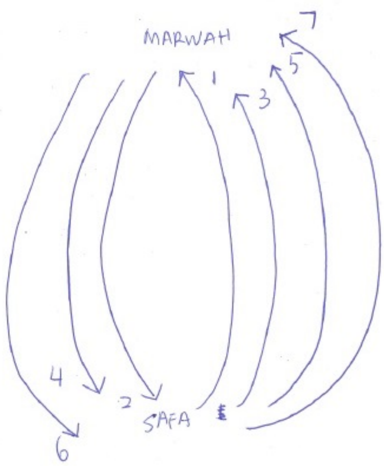


Figure E.4: A man who included a long text description in his drawing



(a)



(b)

Figure E.5: Drawing 9 - 10 of route recognition

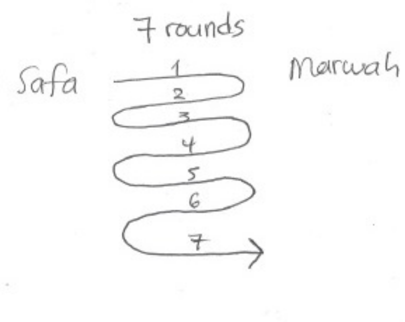
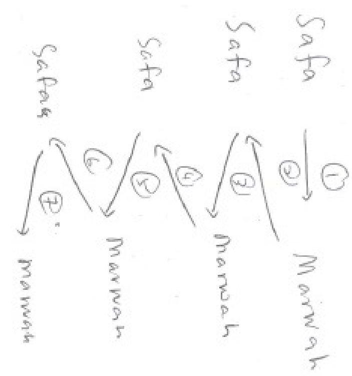
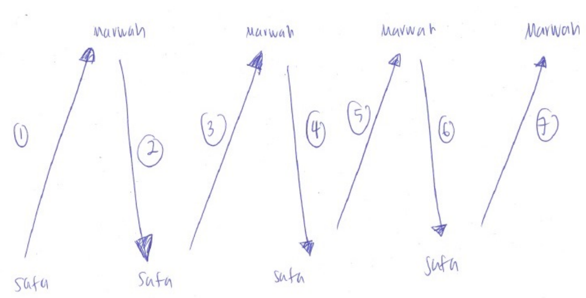


Figure E.6: Drawing 11 of route recognition

The drawing in Figure E.6 is so interesting and was drawn by 1 participant only. The participant positioned Safa hill on the left and Marwah hill on the right of the paper. However, he drew a continuous curved line, like a shape of a snake, to represent all seven rounds. He drew this figure in the Paper 1 and also, in the Paper 2.



(a)



(b)

Figure E.7: Drawing 12 - 13 of route recognition

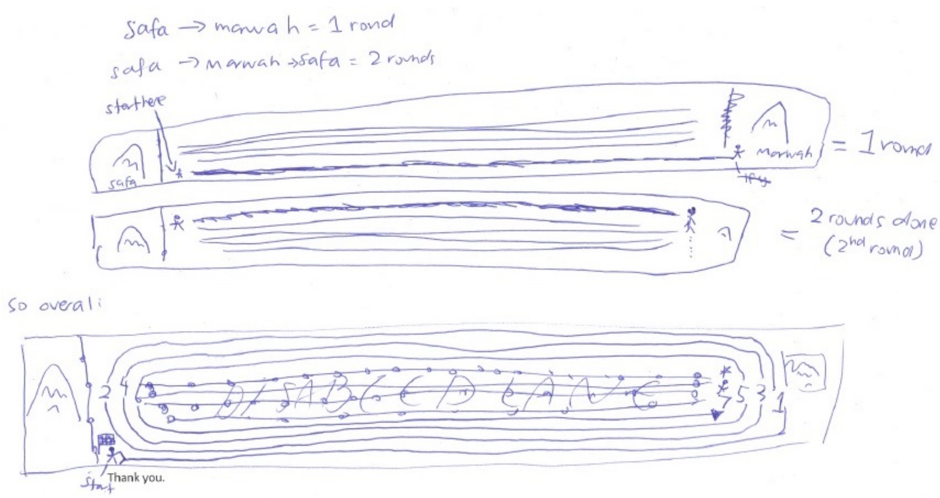
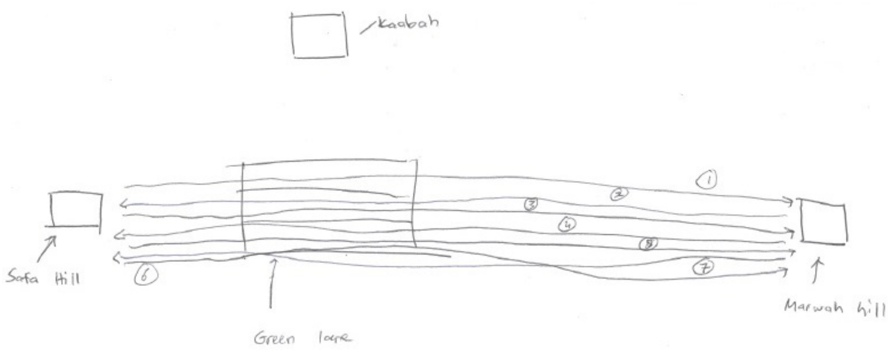


Figure E.8: Drawing 14 of route recognition

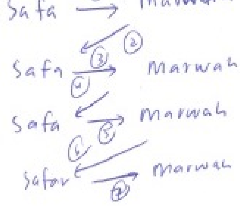
This paragraph and the next paragraph describe the drawings that were performed in the Paper 1 only. Figure E.7 shows two drawings with the similarity of the straight lines representing the rounds were firstly drawn from the north-east to the south-west of the paper, or vice versa. However, the location of hills was different. Each drawing was drawn by 1 participant.

The drawing in Figure E.8 presents that Safa hill was located on the left and Marwah hill on the right of the paper. It also shows four curved lines representing round 1, 3, 5 and 7 from Safa hill to Marwah hill and three curved lines from Marwah hill to Safa hill, indicating round 2, 4 and 6. Only 1 participant drew this figure.

This paragraph and the next two paragraphs describe the drawings that were performed in the Paper 2 only. The similarity in Figure E.9a - E.9d was the rounds were numbered continuously, whether the rounds were drawn from the top to the bottom or from the left to the right of the paper. In the first three drawings, the location of hills was similar, and it was different in the final drawing. Also, the rounds in the first drawing were in straight lines from the left to the right, the next two drawings show the straight lines were firstly drawn from the north-west to the south-east and in the final drawing, the rounds were mixed of curved and straight lines which were drawn from the bottom to the top. The only difference between the second and third drawing was the amount of label of the hills. In the second drawing, a participant labelled Safa and Marwah hill four times, and in the third drawing, it was labelled once only. Each drawing was drawn by 1 participant only.



(a)



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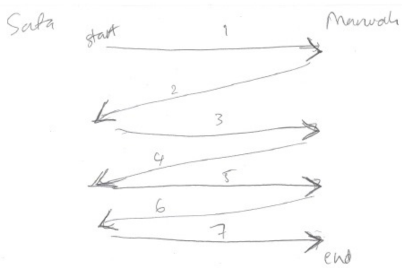

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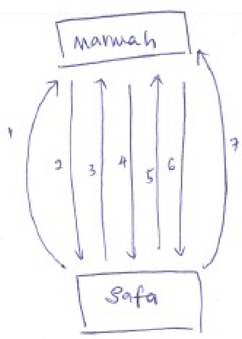
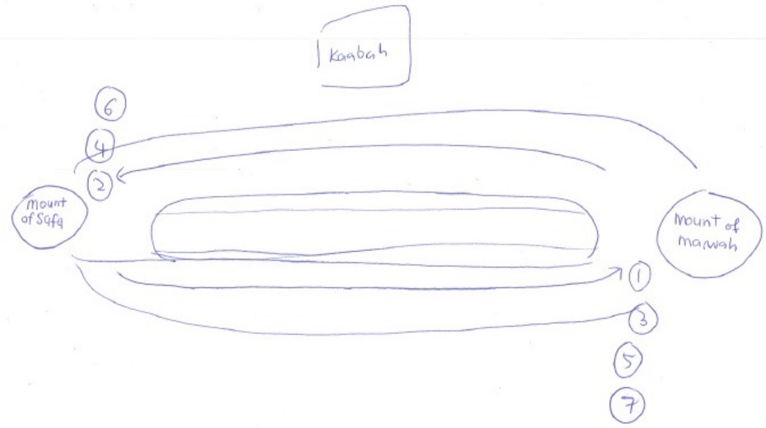
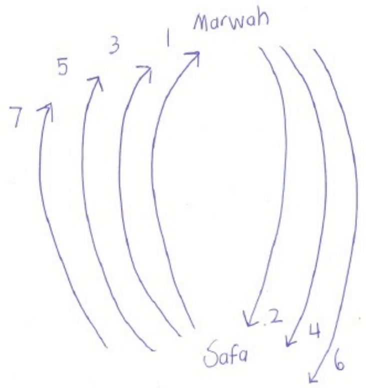


(d)

Figure E.9: Drawing 15 - 18 of route recognition



(a)

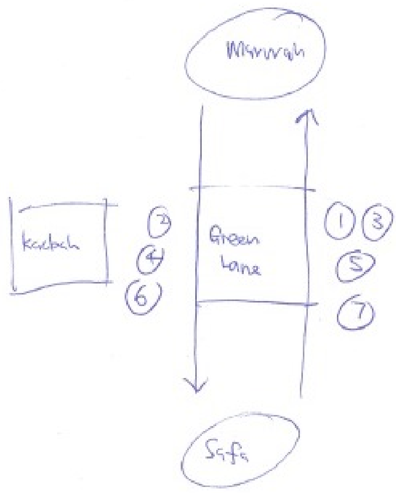


(b)

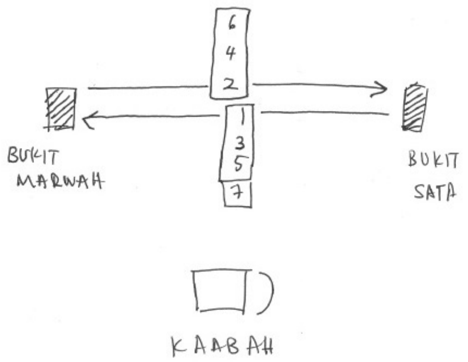
Figure E.10: Drawing 19 - 20 of route recognition

Both drawings in Figure E.10 demonstrate that the curved lines were used to represent the rounds of Sa'ie. The difference between these two drawings was the location of hills. In the first drawing (Figure E.10a), Safa hill was located on the left and Marwah was on the right. In the second drawing (Figure E.10b), Safa hill was at the bottom, and Marwah hill was at the top. Three participants whom all learned from the SG drew the first drawing. By contrast, the second drawing was drawn by 2 participants who learned from the PPT.

There were only two straight lines used to represent the rounds in Figure E.11. However, the location of hills on the paper was different in these three drawings. The first drawing positioned Safa hill at the bottom and Marwah hill at the top (Figure E.11a). The second drawing positioned Safa hill on the right and Marwah hill on the left (Figure E.11b), and the last drawing positioned the opposite (Figure E.11c). The first drawing was drawn by 2 participants, and the next two drawings were drawn by 1 participant each.



(a)



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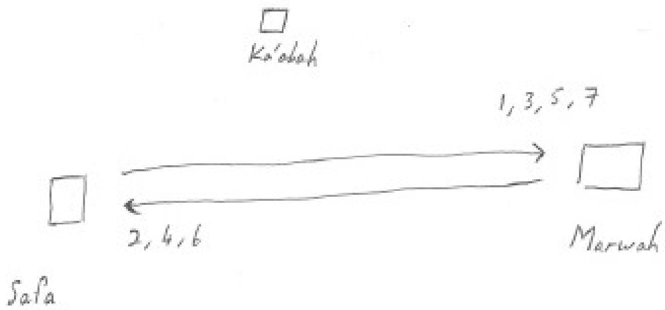

(c)

Figure E.11: Drawing 21 - 23 of route recognition