EXPLORING VERTICAL NAVIGATION WITHIN A VIRTUAL ENVIRONMENT: A STAIRCASE EXPERIENCE

A Ph.D. Dissertation

by
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Ankara
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To My Son

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Graduate School of Economics and Social Sciences
of
İhsan Doğramacı Bilkent University

by

İPEK (SANCAKTAR) MEMİKOĞLU

In Partial Fulfillment of the Requirements for the Degree of
DOCTOR OF PHILOSOPHY

in

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İHSAN DOĞRAMACI BİLKENT UNIVERSITY
ANKARA

July 2012

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Doctor of Philosophy in Art, Design and Architecture.

Prof. Dr. Halime Demirkan
Supervisor

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Doctor of Philosophy in Art, Design and Architecture.

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Approved by the Graduate School of Economics and Social Sciences

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ABSTRACT

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Memikoğlu, İpek

Ph.D. in Art, Design and Architecture

Supervisor: Prof. Dr. Halime Demirkan

July, 2012

Architectural cues are configured by architects in the initial phase of design process. Local architectural cues within an environment can aid individuals during navigation and influence their spatial orientation. Staircases, as a feature of local architectural cues that provide access to the other floors in a multi-level building can have an impact on vertical navigation. This study focuses on the issue of vertical navigation during virtual navigation by integrating the individual characteristics and the geometric attributes of a staircase pair within two different multi-level desktop virtual environments (VEs). The angle between the cue pairs with respect to the same observation point is altered in order to determine the staircase pair that is more efficient in navigation. Circulation paths, gender differences, navigational abilities and cue pairs are considered to be factors that affect staircase preferences for ascending and descending. For the VE with a 180° difference between the cue pairs, there was a relationship between the ascending and descending staircases. Further analysis indicated that the staircase preference in ascending was either related to the first or last visited rooms on the ground floor. For the VE with a 90° difference between the cue pairs, no relationship was found between the ascending and descending staircases as well as with any other factor. There was no significant relationship between gender and staircase preference except for the descending staircase with 180° difference between the cue pairs and was in favor of females. In addition, there was no significant relationship between the navigational abilities and staircase preferences.

Keywords: Architectural Cues, Gender, Geometric Attributes, Staircases, Vertical Navigation, Virtual Environments

ÖZET

SANAL ORTAMDA DİKEY NAVİGASYONUN İNCELENMESİ:
BİR MERDİVEN DENEYİMİ

Memikoğlu, İpek

Doktora, Güzel Sanatlar, Tasarım ve Mimarlık Fakültesi

Tez Yöneticisi: Prof. Dr. Halime Demirkan

Temmuz, 2012

Mimari işaretler, mimarlar tarafından tasarım sürecinin ilk aşamasında yapılandırılmaktadır. Lokal mimari işaretler, bireylerin mekan içinde navigasyonlarına destek olarak, onların mekansal yönlendirmelerini etkiler. Lokal mimari işaretlerden biri olan merdivenler, çok-katlı bir binada diğer katlara erişim sağlamakta ve dikey dolaşım sürecini etkilemektedir. Bu çalışma sanal navigasyon sırasında, iki çok-katlı masaüstü sanal ortamda, bireysel özellikler ile bir çift merdivenin geometrik niteliklerini birleştirerek dikey navigasyon konusuna odaklanmaktadır. Navigasyon sırasında en etkin merdiven çiftini belirlemek için, sabit gözlem noktasına göre işaret çiftleri arasındaki açı farklılaştırılmıştır. Dolaşım şekli, cinsiyet farkı, navigasyon becerileri ve işaret çiftleri; merdivenlerdeki yukarıya çıkış ve aşağı iniş tercihlerini etkileyen faktörler olarak düşünülmüştür. Merdiven çiftleri arasında 180° fark olan sanal ortamda, yukarıya çıkış ve aşağı iniş merdivenleri arasında bir ilişki bulunmuştur. İleri analizler, merdivendeki yukarıya çıkışın giriş katındaki ilk ya da son ziyaret edilen odaya göre tercih edildiğini göstermektedir. Merdiven çiftleri arasında 90° fark olan sanal ortamda, hem yukarıya çıkış ve aşağı iniş merdivenleri hem de başka faktörler arasında bir ilişki bulunamamıştır. Cinsiyet ve merdiven tercihleri arasında anlamlı bir ilişki bulunmamış olup, sadece bayanlar tarafından işaret çiftlerinin arasında 180° fark olan aşağı inen merdivende anlamlı bir ilişki bulunmuştur. Ayrıca, navigasyon becerileri ve merdiven tercihleri arasında anlamlı bir ilişki bulunmamıştır.

Anahtar Sözcükler: Cinsiyet, Dikey Navigasyon, Geometrik Nitelikler, Merdivenler, Mimari İşaretler, Sanal Ortamlar

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CHAPTER 1

INTRODUCTION

Architectural design is the science and art of building that generally encompasses a broad diversity of task such as conceptualization, organization and construction of the built environment. It is a problem-solving activity that influences the comprehension and knowledge of spatial orientation and navigation in the built environment (Hölscher et al., 2005). While developing the spatial organization of an environment, the designer needs to determine the nature of the wayfinding problems that future users will encounter (Passini, 1996). Hölscher et al. (2005) indicated that developing an architectural space that is adequate and satisfactory is an essentially spatial task. Architectural space is constantly generated in respect to the existing environment and accordingly in a high-dimensional decision space (Hölscher et al., 2005). Decision-making in architectural design consists of processes that utilize external representations in a range of different spatial formats (Freksa et al., 2004).

In the theory of architectural design, the idea of movement is emphasized as a central theme. In order to understand a building's interior structure and spatial organization, one needs to make her/his way through the building. "To experience architectural space truthfully it is necessary to perambulate and stride the building" (Le Corbusier, 1962: 30, cited in Hölscher et al., 2005). Hölscher et al. (2005) stated that we do not experience the spatial layout of a building as a static structure, but perceive it as a result of movement; we discover architectural cues step by step.

Architectural cues are crucial cues configured by architects in the initial design phase of the design process. Various local architectural cues within an environment can aid individuals during navigation and influence their spatial orientation. With the aid of virtual environments (VEs) local architectural cues can be designed with varying configurations according to the needs of its users. VEs offer their users to navigate in real time and record their navigation behavior.

Staircases, as a feature of local architectural cues can be problematic during vertical circulation since they cause individuals to become disoriented (Soeda et al., 1997). Emphasis is given on staircases since they are one of the main local architectural cues that provide access to the other floors in a multi-level building. Both 'local architectural cues' and 'vertical circulation' terms are considered separately in various fields by focusing on their qualitative properties; however, in this study, the role of the local architectural cues is examined during vertical navigation in a desktop VE.

1.1 Aim of the Study

Architectural design, as a problem solving activity, requires experiencing the spatial organization of a building, discovering local architectural cues and maintaining spatial orientation during navigation. In order to understand the spatial reasoning in architectural design, one needs to consider the factors that affect the spatial updating of the individual in an environment.

The aim of this study is to provide an understanding on how local architectural cues, especially staircases with respect to their geometric attributes, are utilized during vertical navigation and how they influence the individual's vertical navigation behavior in a multi-level desktop VE. In addition, it aims to examine local architectural cues from an interior architectural perspective and at the end propose a guideline for interior architects. This study utilizes the VE as a medium for investigating the role of staircases since the geometric attributes of the staircases can be varied systematically in order to understand their influence on vertical navigation. Vertical navigation is examined by integrating the characteristics of the individuals and the staircase preferences within two different multi-level desktop VEs. This thesis points out the difference between the staircases with respect to their geometric attributes and individual characteristics and tries to understand their utilizations.

1.2 Structure of the Thesis

The thesis consists of six chapters. The first chapter is the introduction in which the importance of architectural design with respect to architectural cues is stated and how the staircase, as a local architectural cue, affects vertical navigation in a VE is investigated. The second chapter explores the concepts of navigation, frames of reference, architectural cues and staircases as architectural cues. Firstly, navigation is defined with respect to the travel techniques and navigation strategies. Secondly, during navigation the locations of the spatial representation are presented according to the frames of reference that are identified as the egocentric and environmental subsystems. Next, global and local architectural cues in an environment are defined in relation to architectural cues. Lastly, the importance of staircases as architectural cues is described. In the third chapter, individual differences that consist of gender differences, sense of direction, sense of presence, and previous experience with respect to computer familiarity and computer games are explained.

The fourth chapter states the aim, research questions and hypotheses, describes the proposed model with respect to the participants and virtual environment, and identifies the instruments and software that will be utilized in the study that are 'Santa Barbara Sense of Direction Scale' (SDSOB), 'Computer Aversion, Attitudes and Familiarity Index' (CAAFI), 'Igroup Presence Questionnaire' (IPQ), observation sheet and computer experience questionnaire, and 'Second Life'.

In the fifth chapter, an experiment is formulated with respect to the proposed model; the participants are identified and the procedure of the experiment is defined.

Finally, the results are evaluated and discussed in relation to previous studies related to the subject. In the last chapter, major conclusions about the study are stated, a guideline for interior architects is proposed, various strengths and limitations of the study are stated, and suggestions for further research are generated.

CHAPTER 2

VIRTUAL ENVIRONMENTS (VEs)

With the increase in computer usage, VEs have become new areas of navigation. They allow simulated exploration of three-dimensional (3D) environments from a view-centered perspective, allow the creation of environments with different complexity, allow the researchers to have greater control over visual features and complexity of the environment than the real world environments and allow interactive navigation with continuous measurements within it (Belingard and Peruch, 2000; Moffat et al., 2001). Behavior of the individuals within the environment can be recorded and assessed separately. VEs have become a tool for spatial knowledge acquisition since they offer the opportunity of controlling and manipulating the characteristics of a real world environment. Kirschen et al. (2000) indicated that VEs are used effectively in tests of spatial learning. Spatial knowledge acquired through learning the VEs can be effectively transferred to subsequent navigation in the real world environments (Lessels and Ruddle, 2005; Waller et al., 2001). Waller (2000) demonstrated that spatial knowledge acquired in the VE translates well to the real environment.

A VE for architectural use allows interior architects and clients to obtain an immersed view of a building by allowing the user to move through the proposed building (Cutmore et al., 2000). It enables the individual to visualize and interact with the virtual, 3D proposed spatial environment in real time (Çubukcu and Nasar, 2005).

2.1 Navigation

Architectural design is a problem solving activity that requires perceiving the spatial layout, navigating and making inferences about spatial relationships. Navigation is a core functional requirement that individuals perform in VEs (Santos et al., 2009). It is a spatial activity that is guided by visual information of the environment (Zhang, 2008). Bell and Saucier (2004: 252) stated that navigation is "a complex spatial problem that is routinely faced and solved by humans and other animals". Navigation is a dynamic process where the task and the environment in which it takes place, affects the way a person moves (Särkelä et al., 2009). It can take place in familiar environments or in novel environments in which an individual has little or no prior experience; it can also occur in large environments that are difficult to perceive from a single point. In order to navigate successfully the individuals need to plan their movements using spatial knowledge gained about the environment and stored as mental map (Santos et al., 2009).

Montello and Freundschuh (2005) indicated that navigation is a coordinated and goal directed movement through a space that consists of two parts, travel (locomotion) and wayfinding. Travel is the actual motion from the current location to the new location, changing the position of the viewpoint (Zhang, 2008). It can be referred to as “the perceptual-motor coordination to the local surrounds, and includes activities such as moving towards visible targets and avoiding obstacles” (Montello and Freundschuh, 2005: 69). The second constituent of navigation is wayfinding that refers to the “cognitive coordination to the distant environment, beyond direct sensorimotor access, and includes activities such as trip planning and route choice” (Montello and Freundschuh, 2005: 69) where the path is determined by knowledge of the environment, visual cues and navigational aids. In other words, wayfinding is “the strategic and tactical element that guides movement” (Sadeghian et al., 2006: 2). Therefore, people are aware of their current positions and of how to reach the desired goal. Zhang (2008) stated that wayfinding emphasizes the mental processes of navigation while travel emphasizes the physical processes to execute navigation plans.

Jul and Furnas (1997) designed a general framework for the navigation process for a VE that incorporated the motion component into the mental process (see Figure 1). They identified the important factors in navigation such as forming navigation goals, perceiving spatial knowledge, moving and accessing navigation results (Zhang, 2008). The model starts with a goal-forming step followed by strategy selection. After the selection of the strategy, a tight loop consisting to perception, assessment, cognitive map and motion is processed.

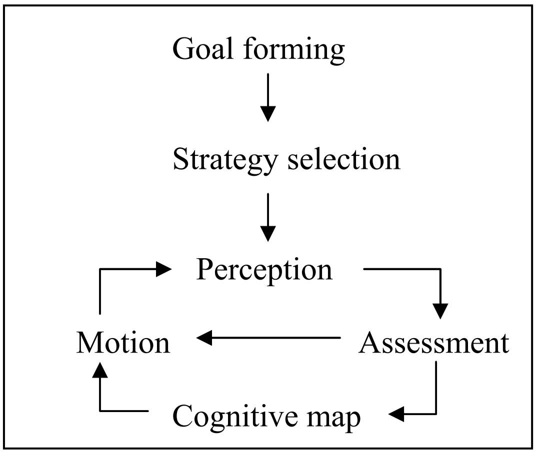

Figure 1. A general framework for the navigation process for a VE (Adapted from Jul and Furnas, 1997).

Likewise, building upon Jul and Furnas' (1997) framework, Chen and Stanney (1999) developed a general model of navigation in which they divided the navigation tasks into three subtasks of cognitive mapping, decision making, and decision execution (see Figure 2). The model is partitioned into two sections as wayfinding and navigation that reflect the cognitive and motion based components of the process.

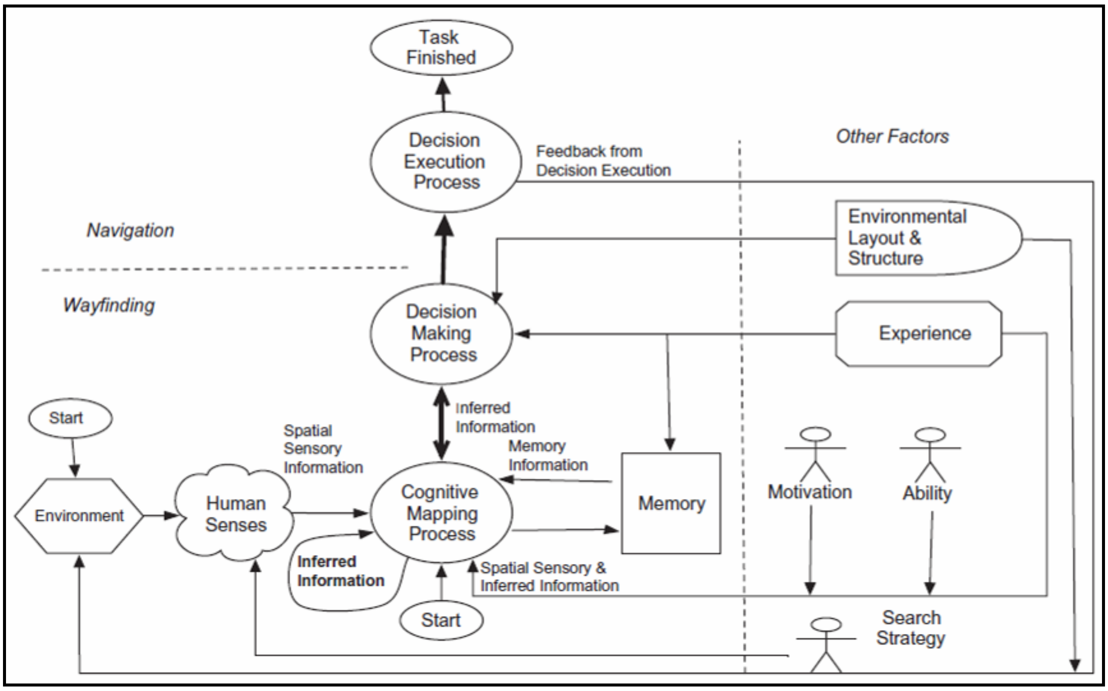

Figure 2. Navigation model (Martens and Antonenko, 2012: 811; adapted from Chen and Stanney, 1999).

Navigation in the VEs is based on visual movement and the participants navigate with the help of an interface. The most common interface for navigating is mouse and buttons (Burdea and Coiffet, 2003). Although, navigating with a mouse is seen different from actual walking, Zacharias (2006) claimed that the basic movement strategy in well-built VE is similar to the movement strategy in the real environment. "Findings from movement in the VE can, with certain restrictions, be generalized to movement in the real environment" (Särkelä et al., 2009: 788).

2.1.1 Travel Techniques

Since travel and wayfinding are closely related, the method of travel can have an effect on the ability to perform wayfinding tasks and in determining spatial orientation (Bowman et al., 1999). Bowman et al. (1997; 1998) asserted that travel control is as important as spatial knowledge access. They created a taxonomy of travel techniques in a VE that were based on three subtasks: direction or target selection, velocity and acceleration selection, and input conditions (Figure 3). Direction or target selection refers to the method in which the user 'steers' the direction of travel or selects the goal position of the movement. Velocity and acceleration selection methods allow the user/system to set speed and/or acceleration. Finally, input conditions are the ways in which the user or system specifies the beginning time, duration, and end time of the travel motion (Bowman et al., 1997; 1998). The authors concluded that this taxonomy was useful in three ways: it helped them to understand the space of possible techniques, guided them in designing new techniques (choose a component for each of the three subtasks), and helped them to generate ideas for experimental evaluation of techniques.

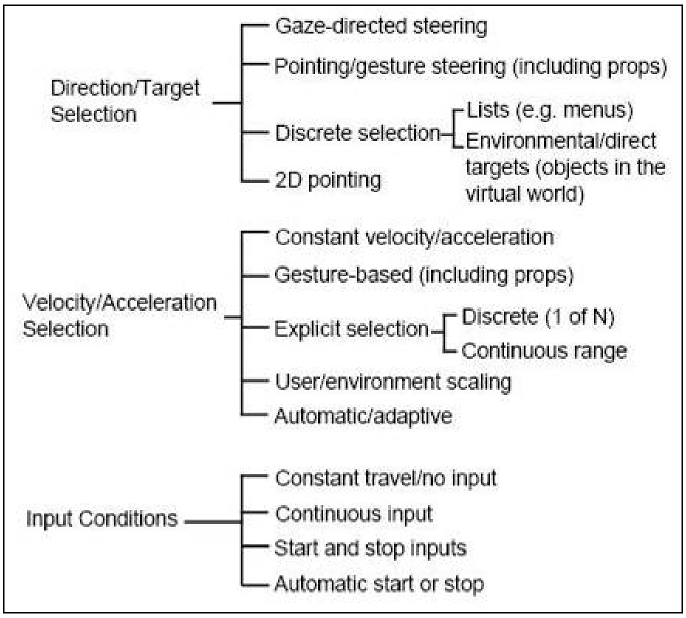

Figure 3. Taxonomy of virtual travel techniques (Bowman et al., 1997: 46)

Later, Bowman et al. (1999) developed another taxonomy that considered travel to be the task of setting one's viewpoint position and orientation in a 3D space (Figure 4). With respect to 'position', three different categories with three important factors were identified; these were position, velocity and acceleration. They categorized virtual travel techniques in a VE as discrete target, continuous and one-time specifications and they distinguished these by the amount of control the users have over their motions. In discrete target specification, the user identifies the target and the system moves the user there, "the user controls the two-end points of motion and leaves the path between those points up to the system" (Bowman et al., 1999: 620). In continuous specification, there is a complete control of the user on the process of moving through an environment. In one-time route specification, there is no control of the user over the motion, in other words, the user defines a path of viewpoint motion and the system moves the user along that path.

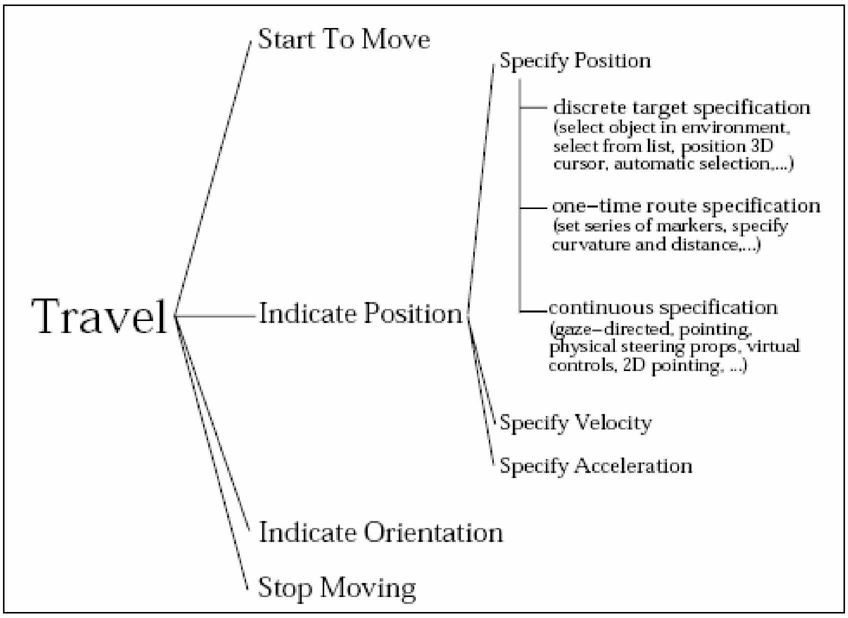

Figure 4. Taxonomy of virtual travel techniques, with detail shown for the 'specify position' subtask (Bowman et al., 1999: 620).

Building upon Bowman et al.'s (1997) framework, Arns (2002, cited in Mabini, 2009) defined travel as the change of location of a viewpoint and divided travel in VEs into two major components as rotation and translation (Figure 5). These components were classified as physical movements, which is the "movement of the user relative to the world" and virtual movements, which is the "movement of the virtual world relative to the user" (Mabini, 2009: 11). In addition, Arns (2002, cited in Mabini, 2009) introduced a classification for interaction and display devices, and portrayed the various ways that they can be combined to create methods of locomotion.

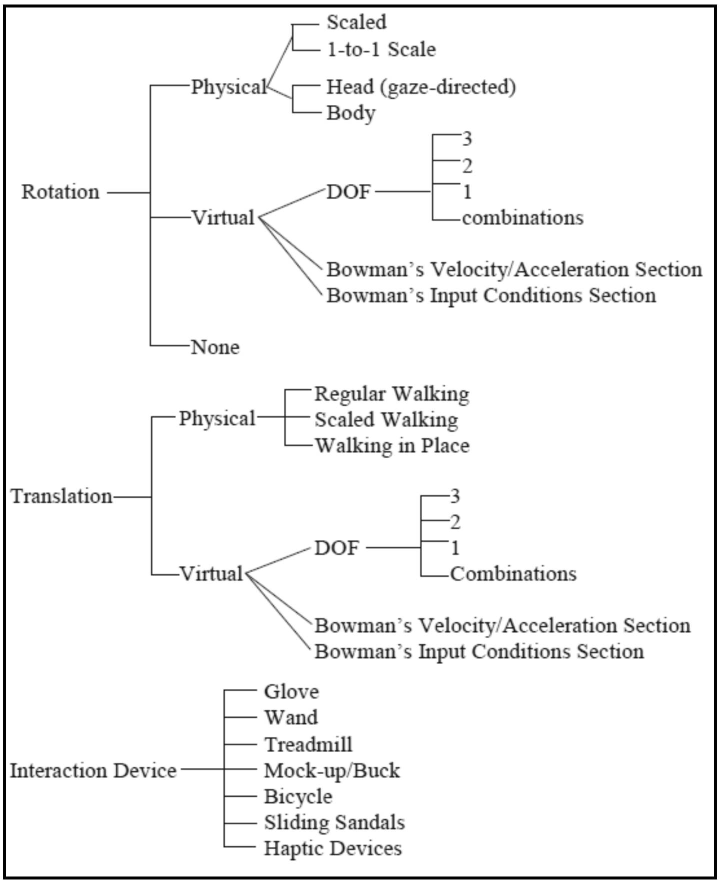

Figure 5. Taxonomy of locomotion (Arns, 2002, cited in Mabini, 2009: 12).

In virtual travel, steering techniques, which allow continuous control of the direction of travel, are mainly used in VEs and they constitute of gaze-directed, pointing-directed and torso-directed steering (Suma et al., 2010). Gaze-directed steering is the simplest and most common method in which travel is in the direction the individual is looking, in pointing-directed steering, travel direction is indicated by the individual's hand and in torso-directed steering, travel direction is indicated by the individual's body. Both pointing-directed steering and torso-directed steering decouple the view direction from the travel direction, allowing the individual to look around while moving (Suma et al., 2010). Bowman et al. (1997) indicated that gaze-directed steering was faster than pointing as a travel technique, but the pointing technique to be more accurate.

With respect to Bowman et al.'s (1997) taxonomy, Jeong et al. (2004) stated that although the techniques using position are efficient for navigating in the VE, travel techniques should adopt velocity or acceleration control that allow individuals to change their velocity of travel for more efficient exploration of the environment (Jeong et al., 2009). Jeong et al. (2009: 45) claimed that "by combining pointing and a velocity control technique, users can navigate a VE by indicating the direction that they want to move toward while controlling the velocity at which they would travel". Various velocity control techniques while using the pointing technique for specifying the target position have been developed. These are count-based (discrete), time-based, gesture-based, force-based and speech-based velocity control techniques.

Count-based velocity control technique increases the velocity according to the number of clicks. Time-based velocity control technique measures the duration of a button press, when the button is held down the velocity increases and when the button is released the velocity decreases. Gesture-based velocity control technique allows the individual to control the velocity based on the distance between the individual's hand and head. Force-based velocity control technique is based on how hard the individual pushes down on a button, which is made with a force-sensing resistor. Finally, speech-based velocity control technique is based on the recognition of different utterances (Jeong et al., 2004; Jeong et al., 2009). Jeong et al. (2009) summarized the results of the five velocity control techniques in Table 1.

Table 1. Summary of the five velocity control techniques (Jeong et al., 2009: 48)

	Mapping	Weakness	Naturalness	Mechanism	Sensitivity
Count-based	Discrete	Finger fatigue	No	Pressing	Low
Time-based	Linear	Finger fatigue	No	Pressing	Low
Gesture-based	Linear	Arm fatigue	Yes	Gesturing	High
Force-based	Approximately linear	Difficult to implement	No	Pressing	High
Speech-based	Discrete	Incorrect recognition	Yes	Uttering	Low

Mapping depicts the type of interaction required by the user. Weakness summarizes the major complaints of the technique. Naturalness denotes whether or not the technique mimics a natural mapping to human actions. Mechanism shows how each technique is used, and sensitivity indicates if the user can quickly change the velocity using each technique

They found that the force-based velocity control technique was more efficient when considering time spent, information gathering ability, amount of collision, sense of presence, ease of learning, ease of use, user comfort and user concentration, whereas, the least effective technique was the count-based velocity control technique (Jeong et al., 2009).

In desktop VEs, the most common travel metaphor used for viewpoint control and navigating architectural buildings is virtual walkthrough (Lapointe and Savard, 2007; Lapointe and Vinson, 2002). Navigation in virtual walkthroughs utilizes various input devices, such as mice, keyboards and joysticks. Lapointe et al. (2011) declared that in virtual walkthroughs, the number of Degrees Of Freedom (DOF) of movement differs from 2 to 4 out of 6. Three of the six DOFs consist of "translation: forward/back, left/right and up/down", and the other three DOFs consist of "rotation: rotation around the axis perpendicular to the travel plane (yaw axis), and rotation around each of the axes forming the travel plane (pitch and roll axes)" (Lapointe et al., 2011: 2186). Lapointe et al. (2011) identified four different travel techniques for virtual walkthroughs. The first travel technique involved a keyboard as the input device that controlled 3 DOFs: 2 translation DOFs, which were fore/aft and left/right (strafe) without any rotation, and a rotation along the horizontal plane around the vertical axis (yaw). The second travel technique was based on a mouse that consisted of two DOFs: one translation (fore/aft) and one rotation (yaw). The third travel technique was a joystick with 3 DOFs: strafe, fore/aft and yaw. The final travel technique consisted of a gamepad with two mini joysticks that controlled 2 translation DOFs: strafe and fore/aft, and one rotation: yaw. In each travel technique, the velocities of the translation and rotation movements were kept constant.

Lapointe et al. (2011) concluded that the mouse travel technique provided better performance than the other travel techniques and subjective ratings indicated that the mouse travel technique provided ease of use, speed, accuracy and overall preference. They indicated that a two-handed travel technique consisting of a keyboard and a mouse would be interesting to test since this travel technique is extensively utilized in first-person 3D computer games.

2.1.2 Navigation Strategies

When people have an imprecise or incomplete spatial knowledge, they need to rely on navigation strategies. Various strategies have been identified for two-dimensional and three-dimensional settings. Hochmair and Frank (2002) and Conroy-Dalton (2003) described 'the least-angle strategy' as the process of selecting the path that had the least deviation from the target direction when the target direction was known, but the environment was unknown at intersections. Wiener and Mallot (2003) investigated the role of environmental regions with a hierarchical planning approach. They developed a cognitive model of region-based route planning referred to as 'the fine-to-coarse planning strategy' in which the environment was cognitively segmented into regions that guided navigation decisions. In the currently occupied region, routes are planned in detail, but coarsely when planning navigation between regions (Spiers and Maguire, 2008). In addition, Wiener et al. (2004) identified two other strategies: 'the cluster strategy' and 'the least-decision-load strategy'. The cluster strategy states that route planning considers the distribution of target locations within an environment, resulting in a preference for paths that allow visiting as many targets as fast as possible. The least-decision-load strategy states that the subjects, when they have the choice of choosing between alternative paths, choose the path that minimizes the number of possible movement decisions (Wiener et al., 2004; Tenbrink and Wiener, 2007).

On the other hand, Hölscher et al. (2006) identified three strategies for finding one's way in 3D settings; these were 'central point strategy', 'direction strategy' and 'floor strategy'. In the central point strategy, the individual stays as close as possible to well-known parts of the building, such as the main entry hall and main connecting corridors. The direction strategy aims at choosing routes that head towards the horizontal position of the goal as directly as possible, regardless of level changes. In the floor strategy, the individual first moves to the correct floor in the building, regardless of the horizontal position of the goal, then starts a fine-tuned search (Hölscher et al., 2005; 2006).

2.2 Frames of Reference

Mou et al. (2004) proposed that the human navigation and spatial representation system consists of subsystems namely as the egocentric and the environmental (allocentric) frames of reference (see Figure 6). The egocentric frame of reference represents object locations in the transient self-to-object relations; it guides interaction with the immediate surroundings. Iachini et al. (2009) stated that egocentric frame of reference is determined by the position of the viewer in the environment and egocentric spatial representations sustain the viewing perspective. Stored spatial information is accessed with respect to the body position of the viewer (Iachini et al., 2009). Alternately, the environmental frame of reference is responsible for representing the spatial environments; it is independent of the viewer's position and is focused on external objects and features of the environment (Iachini et al., 2009). "Interobject spatial relations are represented independent of the observer using allocentric reference frames" (Rump and McNamara, 2007: 253).

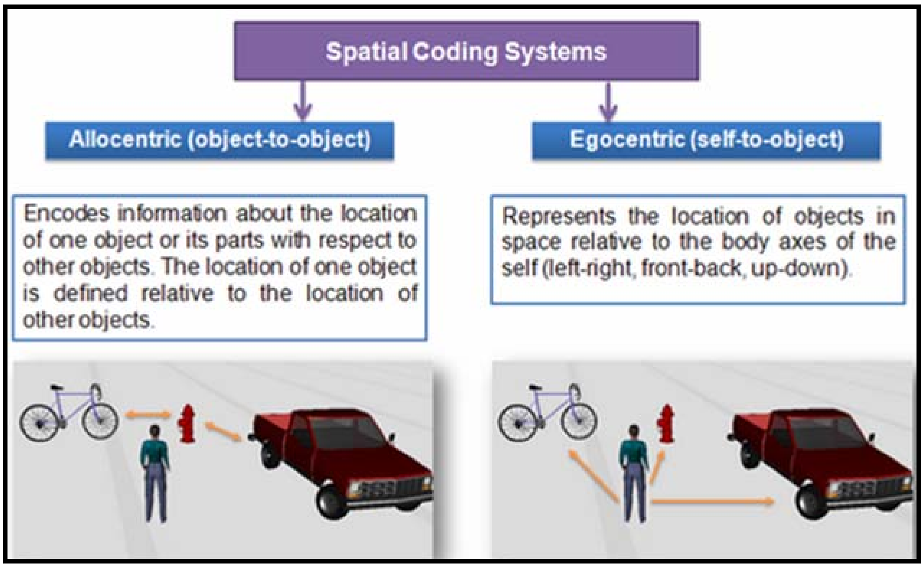

Figure 6. Subsystems of the reference frames (Imagery Lab, n.d.)

When travelling through an environment, updating occurs in both frames of reference. In the egocentric frame of reference, the transient self-to-object relations are updated as long as vision support is available. This updating is efficient and needs minimal attentional control, but egocentric updating becomes more effortful and restricted to a small number of objects when vision support diminishes. Egocentric updating allows an individual to avoid obstacles, keep track of surrounding objects, but it does not prevent her/him from getting lost. In order to stay oriented, the individual needs to know her/his position with respect to familiar objects in the environment and the spatial layout of the objects need to be represented over the long term. These representations are presented in the environmental frame of reference. Updating in the environmental frame of reference consists of "keeping track of location and orientation with respect to the intrinsic reference system used to represent the spatial structure of the environment. Self-to-object and object-to-object spatial relations are specified in the same intrinsic reference system. The body is treated like any other object in the environment" (Mou et al., 2004: 154). When navigating in the VE an egocentric viewpoint that is perceived from the perspective of the user will provide a greater sense of self and awareness of objects in the VE than an exocentric viewpoint, which provides a third person perspective (Ma and Kaber, 2006). Iachini et al. (2009) claimed that when the environment was familiar and was characterized by regular and prominent environmental axes, environmental frame of reference was used, but when it was unfamiliar egocentric frame of reference was utilized.

2.3 Architectural Cues

When people navigate in unfamiliar VEs, the design of the VE should promote rapid information that is necessary for successful navigation and orientation. The navigators need to develop accurate spatial information as quickly as possible when information is represented by the relative size, orientation and position of virtual objects (Vinson, 1999). Navigation and orientation in the VE can be enhanced by the cues that people use while navigating in the real environments. These cues are comprised of all kinds of information that is available in the environment, such as 'verbal', 'graphic', 'architectural' and 'spatial' cues (Sun and de Vries, 2009). Sun and de Vries (2009) asserted that an architectural cue is a crucial one that is configured by the architects in the initial phase during design process. In the initial phase, the architectural space that is composed of architectural elements can offer a variety of meanings (Lawson, 2001; Rapoport, 1982) that can be perceived by users and have an impact on their behavior patterns (Sun and de Vries, 2009). An architectural cue shapes the behavior pattern of the user of the built environment (Sun, 2009). For example, an entrance that is bigger in scale may look more like an entrance and attract more users that a smaller one on the same façade (Lawson, 2001).

Architectural cues do not only indicate a reference to position and orientation, but they also contribute to the development of spatial knowledge. Various guidelines have been proposed by Vinson (1999) in order to support navigation and orientation in a VE such as:

- It is essential that a VE contains several cues; the navigator can determine her/his position in the environment through her/his knowledge of the position of the cues.
- Cues should be made distinctive with their heights, complex shapes, unique exterior colors and textures and be free standing.
- Cues should be chosen from concrete things rather than abstract ones to make them more recognizable.
- Cues must be visible and distinguishable from nearby objects and other cues in order to easily prevent confusion or wrong navigational action in a VE.
- The sides of the cue should be differentiated from each other to help navigators decide their orientation.
- The placement of the cues should be well defined and they should be placed on major paths and at path junctions. By this way, the cue can be more memorable.

Architectural cues are essential in the environment and are not easy to rebuild. They are categorized as global architectural cues and local architectural cues (Sun, 2009).

2.3.1 Global Architectural Cues

Sun (2009) stated that global architectural cues are perceived from the architectural forms and provide information about how the parts of the building are organized globally. They are considered as the only source to form the cognitive map that is perceived through travelling in the environment (Sun, 2009). They can serve as references to absolute location and provide a stable frame of reference (Lin et al., 2012). There are four types of sources in the built environment that provide the global architectural cues. They are the circulation system, the exterior form of the building, the visible structural frameworks and the atrium (Sun, 2009).
According to Arthur and Passini (1992), the circulation system is the main organizing feature and a determining factor for the layout of an environment. Circulation systems are classified into four categories as linear circulations, centralized circulations, composite circulations and circulation networks (scatter-point networks, grid networks and hierarchical networks). In addition, the circulation system determines the space in which people travel, try to understand, find their way and make wayfinding decisions. Arthur and Passini (1992) stated that circulation should not be considered just as a link between spaces, but as a space. When people navigate in the circulation system of a building, they are able to understand the spatial organization and the typology of the system (Arthur and Passini, 1992; Sun, 2009).

The exterior form of a building provides clues about the spatial organization and circulation system and gives “a setting an objectlike quality, which is easy to grasp and to retain” (Arthur and Passini, 1992: 89). Likewise, the visible structural framework inside a building gives clues about the spatial organization. Spatial information such as the symmetry axis, elongation (linear organization) and functional characteristics can be presented by the structural framework (Werner and Schindler, 2004). Furthermore, the atrium provides the individuals with a visual and sometimes auditory access to the spatial organization of the building (Arthur and Passini, 1992). Individuals are able to sense a part of the building's volume and view the different floors of the building (Sun, 2009). Sun (2009: 28-29) claimed that "a single perspective of the space contains more information than the one in a closed floor arrangement". Lawton et al. (1970, cited in Tang et al., 2009) indicated that simple corridor systems and central atrium systems that allowed perceptual access between spaces enhanced orientation . Likewise, Arthur and Passini (1992) suggested that buildings that are organized around an open core enable the users to perceive the form of the circulation system.

2.3.2 Local Architectural Cues

The local architectural cue is based on the features of the architectural elements that are locally perceivable (Sun and de Vries, 2009). In other words, it is a type of information that is perceived from the architectural forms and is based on the abstract 3D geometric features of the local architectural elements, such as doorway entrances, stairs, exits and corridors (Sun, 2009). They can be observed at limited locations and from restricted perspectives (Lin et al., 2012). Local and global architectural cues can aid the formulation of and access to cognitive maps (Lin et al., 2012). Sun (2009) deduced a list of local architectural cues that were considered to be influential during an evacuation from an underground space. These were vertical outdoor light, stair, doorway entrance, raised ceiling, columns, lighted ceiling, escalator, handrail and lift from the most attractive to the least (Sun and de Vries, 2009). In addition, Sun (2009) identified four types of sources that determine the local architectural cues. These consist of type of the architectural element in the circulation system, distance from the architectural element to the individual, scale of the architectural element and angular position of the architectural element with respect to the individual's view (Sun, 2009). The scale of the cue involves the width and the height of the cue.

Likewise, two attributes can be proposed to describe the features of the local architectural cues; geometric attributes and featural attributes. Geometric attributes are structural or surface features in the environment (Lin et al., 2012) and they are "provided by extended environmental surfaces, like the shapes formed by room walls or intersecting streets" (Kelly et al., 2008: 281). Featural attributes consist of non-geometric properties, such as color, texture, figure-ground relationship and complexity that cannot be described in geometric terms (Kelly et al., 2008), but can be easily distinguished from the background (Lin et al., 2012).

2.4 Staircases as Architectural Cues

The local architectural cue like the global architecture cue has a close relationship with the circulation system of the building (Sun, 2009). Arthur and Passini (1992) specified four types of local architectural cues that define a circulation system.

These were the entrance, which gave access to the building, the exit, which indicated where to leave the building, the path, which indicated the direction of movement and where to enter the other spaces, and the vertical access, which indicated where to go in order to change levels within the building (Arthur and Passini, 1992; Sun, 2009).

One of most important local architecture cue that enables vertical circulation in a multi-level building is the staircase. In architecture, the staircase functions as an important circulation node, a vertical interconnection and enables movement between the different levels of the building (Hölscher et al., 2006). Staircases help to combine vertical information during movement and enable the individual to understand the spatial organization of the building (Hölscher et al., 2006). Since vertical circulation is one of the most important aspects of good building design, architects need to consider two key design parameters while designing the staircases. The first one is "the constructional and representational form of its appearance have to be highlighted with respect to the function of the building" and secondly, the position of the staircase has to be designed accordingly with the individual's activity within the building (Hölscher et al., 2006: 297).

Nicoll (2007) stated that staircase use is an underlying activity of purposeful travel and is affected by the way people understand and travel through buildings. Olander (2009) claimed that environmental variables such as staircase location and visibility, staircase and building height and escalator/lift availability have an impact on staircase use. Staircases are likely to be utilized more when they are conveniently located closer to the entrance and are visible. Staircase geometry that comprises of the riser, tread and pitch can influence staircase use. High buildings and high steps result in less staircase use; individuals are likely to climb 9 to 18 step staircases and between 2 to 4 floors. Bungum et al. (2007) suggested that the number of floors in a building is a predictor of stair use; as the number of floors increases, stair use decreases. Staircase use decreases when lifts are more visible and faster; staircases are used for shorter distances, whereas lifts are preferred for longer distances.

Nicoll (2007) concluded that staircase use was influenced by the placement of the staircase rather than the appearance of the staircase. According to Nicoll (2007), the most prominent spatial measures that increased stair usage were stair width and stair type. Stair width is one of the strongest predictors of stair usage because people travelling in groups are more likely to remain engaged in conversation when taking the staircases. In addition, Nicoll (2006) recommended that:

- Staircases should be located directly along the main paths of circulation, at or linking the main entrance to the building.
- Staircases should be located between the entrance and the elevator in order to increase their visibility from the entrance so that they are closer and are more visible than the elevator.
- Staircases should be located so that their first step is visible from the elevator.
- Staircases should be located according to where people are situated in the building so that they are in close proximity and are highly visible. They should be between spaces where people work, come together, travel and the elevator.
- Staircases should be oriented accordingly so that they are visible from the largest area where people travel and they are more visible than the

elevator from the entrance and from multiple directions of travel within the building's main circulation paths.

- Entrance doors to the staircases and the first step of the staircases should be oriented in such a way that they have the fewest turns in direction to enter the staircase from the entrance and the main circulation paths in the building.
- Sufficient stair width should be provided to accommodate people travelling in groups for different purposes, such as social engagement, high occupancy movement and emergency exiting.
- The accessibility between the floors at all levels should be maintained. Staircases should be located within the public area of the building.
- The visibility of the staircases should be increased by providing open staircases.

Within the scope of the study, sources that provide local architectural cues, which are defined by Sun (2009), will be utilized. These are the type of the cue in the circulation system, which is the staircase, the distance from the staircase to the individual, the scale and the angular positions of the staircase in the individual's view.

In a multi-level building, vertical travel is a spatial problem solving activity in which the individuals need to update their spatial orientation within the building without getting disoriented. The next chapter explains the individual differences that can affect an individual's ability to acquire spatial information.

CHAPTER 3

INDIVIDUAL DIFFERENCES IN VEs

Individual differences are one of the important factors that influence navigation. Various aspects of individual differences have been identified, such as age, educational background, learning style and spatial familiarity, but with respect to the case study gender differences, sense of direction, sense of presence and previous experience of the individuals are recognized as the factors that affect an individual's ability to acquire spatial information.

3.1 Gender Differences

Previous studies showed that there are gender differences in the ability to acquire spatial information and navigate through real environments and VEs. This may be the result of the different type of information that males and females focus within their environments (Sandstrom et al., 1998; Saucier et al., 2003; Tlauka et al., 2005). Studies have shown that males and females employ different types of strategies and focus on different properties of the environment (Sandstrom et al., 1998).

Sandstrom et al. (1998) reported that males and females use different navigational strategies during the self-report measures. Males employed an Euclidean approach in navigating to a target, using cardinal directions and absolute distance (allocentric strategy), whereas females used a topographic strategy that relied more on visual landmarks and egocentric directions (i.e. left/right) (egocentric strategy) (Barkley and Gabriel, 2007; Chai and Jacobs, 2009; Chen et al., 2009; Coluccia and Louse, 2004; Dabbs et al., 1998; Picucci et al., 2011; Sandstrom et al., 1998; Saucier et al., 2003; Tlauka et al., 2005). Males formed a more accurate representation of the Euclidean or geometric properties, whereas females formed a more accurate representation of the landmarks in the 2D environment (Sandstrom et al., 1998). Females are superior at using landmark-based strategies when navigating and they have better memories for identity and location of landmarks, whereas males have enhanced knowledge of the Euclidean properties of the environment that are distance and directional cues (Dabbs et al., 1998; Iachini et al., 2005; Sandstrom et al., 1998; Saucier et al., 2003).

Devlin and Bernstein (1995) tested how males and females utilized different types of wayfinding information. They concluded that males preferred to use visual-spatial cues more than females in a computer simulated campus tour. Likewise, Sandstrom et al. (1998) indicated that females rely mainly on landmark information, while males use both landmark and geometric information in which landmarks and room geometry were the distal cues in a VE navigation task. In addition, when landmark and geometric information were available, males were faster than females at reaching a hidden target.

When people give navigational directions to others, females refer more to cues and other visual objects along a route. They also show greater accuracy in recalling cues and in estimating distances to cues, and report using a route-based navigation strategy. They provide more landmark information than do men. On the other hand, it is reported that males use more cardinal directions, often provide more cardinal descriptions and use an orientation strategy (Cherney et al., 2008; Dabbs et al., 1998; Hund et al., 2008; Hund and Minarik, 2006; Iachini et al., 2005; Lawton and Morrin, 1999; O'Laughlin and Brubaker, 1998; Sandstrom et al., 1998; Saucier et al., 2003).

Dabbs et al. (1998) suggested that the memory of object location assisted the use of landmarks in navigation, whereas 3D visualization developed the use of abstract Euclidean navigation. Lavenex and Lavenex (2010) indicated that although females and males exhibit different strategies when solving a real world spatial relational memory task in which females considered the local cues and males considered the local and spatial cues, they did not differ in their overall ability and accuracy to solve the task. In addition, males and females differ in the amount of attention that is given to the objects in the environment. Females have better object memory than males in remembering the location and identity of previously viewed objects (Barkley and Gabriel, 2007; James and Kimura, 1997; Levy et al., 2005; Voyer et al., 2007). Barkley and Gabriel (2007) claimed that the female superiority in object memory may be the result of females using positional, landmark-based strategies for navigation. James and Kimura (1997) found that when location and identity of an object were to be integrated females outperformed males; females showed better location memory performance. Similarly, Levy et al. (2005) found a female advantage in the memory of object locations. On the other hand, some studies found no gender difference in object identity recognition (De Goede and Postma, 2008; Iachini et al., 2005).

There has been a significant advantage of males for spatial route learning through an unfamiliar environment and on tasks requiring survey knowledge, for example pointing directions, drawing a sketch map and estimating travel distances (Castelli et al., 2008; Coluccia et al., 2007; Çubukcu and Nasar, 2005; Devlin and Bernstein, 1995; Lawton and Morrin, 1999; Moffat et al., 1998; O'Laughlin and Brubaker, 1998; Tlauka et al., 2005) and males having better navigational performance than females (Chen et al., 2009). Females reported a higher level of anxiety than do men about performing spatial tasks, were less confident than men when drawing maps of a floor plan and having a greater feeling of uncertainty when navigating in a building (Lawton and Kallai, 2002; Lawton et al., 1996; O'Laughlin and Brubaker, 1998). However, Iachini et al. (2005) found no gender difference in object recognition and in remembering absolute distance and categorical spatial relations, but males were better than females in remembering the distance between the objects and the size of the layout. In addition, Sancaktar and Demirkan (2008) found no gender differences in a spatial updating task in a VE. Both males and females could orient themselves within the VE and accurately identify the relative positions of various areas in the VE.

Tlauka et al. (2005) expressed that gender was a predictor of spatial performance in the real world and in the VEs. With respect to the acquisition of spatial knowledge through virtual navigation, an inconsistent pattern of gender differences were revealed. Some studies reported a male advantage in a virtual maze navigation task

(Lawton and Morrin, 1999; Moffat et al., 1998; Sandstrom et al., 1998; Waller, 2000); however, no gender difference was indicated in spatial knowledge tests in VEs (Darken and Sibert, 1996; Sancaktar and Demirkan, 2008; Wilson et al., 1997).

3.2 Sense of Direction

Besides gender differences, sense of direction or "awareness of orientation or location" is an important individual difference (Kozlowski and Bryant, 1977: 178, cited in Padgitt and Hund, 2012). According to Sholl et al. (2000: 17), sense of direction is "the knowledge of the location and orientation of the body with respect to the large stationary objects, or landmarks, attached to the surface of the earth". The sense of direction is related to the ability to update one's orientation and location in space with body movement in the environment (Hegarty et al., 2002), also it is related to people's ability to maintain their orientation to distal landmarks (Sholl et al., 2000). Kozlowski and Bryant (1977, cited in Padgitt and Hund, 2012) considered sense of direction as a cognitive ability that could aid individuals during navigation. Passini (1984) emphasized that sense of direction may be related to self-evaluation of environmental knowledge, whereas Sholl (1988, cited in Heth et al., 2002: 310) emphasized that sense of direction may be related "to the ability to mentally coordinate egocentric and imagined frames of reference. She suggested that this skill is important for learning new environments and orienting within obscure environments".

According to Allen (1999), the sense of direction is the key to the success of orientation behavior; people with a poor sense of direction usually cannot find the destination easily during travelling. They are more likely to lose their way, worry about becoming lost, and feel more anxious when they are lost (Sholl et al., 2000). People with a good sense of direction explore and focus on details in new environments, give and follow directions and they remember new routes better than do people with poor sense of direction (Sholl et al., 2000). Likewise, Heth et al. (2002) stated that people with a good sense of direction can seek for landmarks and utilize them during their navigation, and orient the mental representation of the landmark configuration to correspond with the perceived environment (Cornell et al., 2003).

Sense of direction can be measured by using behavioral tasks, for example pointing to non-visible locations is the most common method (Heth et al., 2002). According to Sholl et al. (2000: 17), a behavioral measure of sense of direction is "the accuracy of people's pointing responses to familiar, but non-visible, landmarks in the surrounding environment". Kozlowski and Bryant (1977, cited in Heth et al., 2002) found no difference between participants who rated themselves with either a good or poor sense of direction when pointing to locations in an unfamiliar tunnel complex. Participants who rated themselves with a good sense of direction showed improvements in pointing accuracy over four walks through the complex. Sholl (1988, cited in Cornell et al., 2003) indicated that participants with a good sense of direction were more accurate at pointing to landmarks when they had to imagine a viewpoint that was not aligned with their forward facing. In another study, Kato and Takeuchi (2003) guided female participants through a route and then asked them to find their way by themselves. Participants with a good sense of direction showed better performance on route learning than participants with a poor sense of direction. Likewise, when Cornell et al. (2003) asked their participants to rate their sense of direction, correlations between self-ratings and accuracy of pointing to imagined landmarks, accuracy of path choices during a route reversal and detour, and speed at performing shortcuts were found. Hund and Nazarczuk (2009) found that participants with larger pointing errors exhibited more wayfinding errors and took longer when navigating in a campus building than participants with smaller sense of direction errors.

Hegarty and her colleagues (2002) developed a standardized self-report scale, a 15 item Santa Barbara Sense of Direction Scale (SBSOD) to assess the effect of sense of direction on various spatial tasks (see Appendix A). When people rate their sense of direction as good or poor, they are basing their judgments on environment tasks such as wayfinding, remaining oriented in an environment, learning layouts, using maps to navigate and giving and following directions. The SBSOD reflects the ability to orient oneself in an environment (Hegarty et al., 2002). Once the scores on the items containing negative statements have been inverted, the total score is calculated by totaling the individual scores. Higher scores on the scale are correlated with more accuracy when pointing to unseen landmarks and to the starting point of a path followed during wayfinding.

Previous studies asserted that people's self-ratings of sense of direction are reliable predictors of spatial orientation and wayfinding, and sense of direction is positively correlated with orientation strategies and negatively correlated with route strategies

(Hegarty et al., 2006; Hund and Nazarczuk, 2009; Kato and Takeuchi, 2003; Prestopnik and Roskos-Ewoldsen, 2000; Sholl et al., 2000). Padgitt and Hund (2012) demonstrated that self-reports of sense of direction and wayfinding were related. They found that people with a good self-reported sense of direction indicated higher ratings to survey descriptions consisting of cardinal directions, distances, left-rights and choice point landmarks, and made fewer wayfinding errors than did people with a poor self-reported sense of direction (Hund and Padgitt, 2010; Padgitt and Hund, 2012). In addition, they indicated that people with a poor sense of direction may be disadvantaged in finding their way through a new environment or deviating from a given path, they can overcome these problems with training and practice (Hartley et al., 2003; Hund and Nazarczuk, 2009).

There are controversial results related to gender differences with respect to sense of direction. Cornell et al. (2003) did not find a consistent gender difference in the wayfinding task; however, female participants rated their sense of direction as worse than males. Females were less accurate and slower than males in estimating bearings form imagined vantage points and performing shortcuts. Hund and Nazarczuk (2009) did not find a gender difference in the behavioral sense of direction pointing task; however, female participants reported a lower sense of direction in the self-report measure. Castelli et al. (2008) found no gender differences in the self-report measure.

3.3 Sense of Presence

VEs enable people to experience, navigate and interact with virtual cues intuitively in real time. During this interaction, they often experience a sense of being in the VE that is referred to as presence. In order to be fully spatially present in the VE, the individual has to forget about the physical environment and accept the VE as the only reference frame (Riecke, 2003). In addition, the VE should be immersive and easy to use so that the participant does not pay attention to the equipment and experiences a sense of being there in the VE.

Presence is a multi-dimensional construct with various definitions and concepts such as spatial presence, social presence and co-presence (Lee and Kim, 2008). According to Lombard and Ditton (1997), presence is a perceptual illusion of non-mediation in which the technology becomes invisible and unnoticed by the user. Slater and Wilbur (1997: 604) defined it as a "state of consciousness, the (psychological) sense of being in the virtual environment". Sadowski and Stanney (2002: 791) described presence as "a sense of belief that one has left the real world and is now 'present' in the virtual environment". Presence implies that observers perceive their self-orientation and self-location with respect to the environment (Riecke, 2003; Wissmath et al., 2011). Presence is experienced "when the users accept the medium as primary egocentric reference frame and when they reject the immediate environment as primary egocentric reference frame" (Wissmath et al., 2011: 1809).

Similarly, Witmer and Singer (1998: 225) defined presence as "the subjective experience of being in one place or environment, even when one is physically situated in another" and "experiencing the computer-generated environment rather than the actual physical locale". They argued that experiencing presence in a VE relied on the ability to focus on coherent stimuli in the VE to the exclusion of the unrelated stimuli in real life. As participants focus their attention, they become psychologically involved and attached to the VE stimuli or activities. In addition, participants can be immersed that is the "psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences" (Witmer and Singer, 1998: 227). They stated that involvement and immersion are necessary for experiencing presence, and higher degree of involvement and immersion in a VE would result in a higher sense of presence.

Likewise, Schubert et al. (1999) used the term spatial presence in order to indicate "the sense of being in a physical space or virtual environment (VE) and having a mental representation of one's own body as a part of a space or VE" (Lee and Kim, 2008: 491). They proposed an embodied presence model, which was built upon the embodied cognition approach of Glenberg (1997) and described the cognitive processes that lead to presence (Regenbrecht and Schubert, 2002; Schubert et al., 1999; 2001). They indicated that presence developed from the cognitive representation of possible actions that could be performed in the VE, in other words, the VE is conceptualized in terms of possible actions. A mental representation of the environment is made in terms of patterns of possible actions, based on perception and memory. These actions, which are represented mentally, are bodily actions within the VE and functionally related to navigation, manipulation of objects or interactions with other agents (Regenbrecht and Schubert, 2002; Schubert et al., 2001). "A sense of presence develops from the mental representation of movement of the own body (or body parts) as a possible action in the VE, or from meshing (Glenberg, 1997) of bodily actions with objects or agents in the VE" (Regenbrecht and Schubert, 2002: 426). They argued that sense of presence consists of two components: construction of a mental model, which is "the sense that we are located in and act from within the VE" and attention allocation, which is "the sense that we are concentrating on the VE and ignoring the real environment" (Schubert et al., 2001: 269). "Users who place themselves in the virtual space by navigating and interacting with the objects are more likely to experience presence as they mentally remove themselves from the real to the virtual world" (Alsina-Jurnet and Gutiérrez-Maldonado, 2010: 791).

There are two methods of measuring the degree of presence that a user experiences in a VE: objective and subjective measures (Thornson et al., 2009). Objective or behavioral measures are performed by observing the automatic responses of the participants during the virtual experience. These automatic responses consist of the participant's heart rate, skin temperature, skin conductance, blood pressure, muscle tension, respiration rate, ocular response and posture. Subjective measures rely on the self-assessment of the participant and they are accumulated by pretest and/or post-test (Thornson et al., 2009).

The most commonly used measures in the presence research are the use of subjective ratings through questionnaires since presence is a subjective experience (Sadowski and Stanney, 2002; Schuemie et al., 2001). Sadowski and Stanney (2002: 797) pointed out that:

> These rating scales generally comprise statements relating to the extent to which an individual: feels physically located in a VE; senses that a VE has become more real than the physical world; and has a sense that the VE is more than merely a mediated event and has transcended into something they have actually experienced.

Schubert and his colleagues (2001) used a rating scale to assess presence in a 3D computer game. The Igroup Presence Questionnaire (IPQ) comprises 14 items rated on a seven-point Likert scale (see Appendix D). The IPQ consists of three subscales that measure different dimensions of presence and one additional general item that assesses the "sense of being here" (in the computer generated world I have a sense of "being there"). The subscale 'Spatial Presence' assesses the sense of being there in the VE (e.g. I had a sense of acting in the virtual space, rather than operating something from outside). The subscale 'Involvement' measures the attention devoted to the real environment and the VE (e.g. I was not aware of my real environment), and the subscale 'Realness' measures the reality judgment of the VE (e.g. how much did your experience in the virtual environment seem consistent with your real world experience?).

The experience of presence in VEs can vary according to individual differences and to the characteristics of media form and media content (Alsina-Jurnet and Gutiérrez-Maldonado, 2010; Hou et al., 2012; Lee and Kim, 2008; Lessiter et al., 2001; Lombard and Ditton, 1997; Sacau et al., 2008). Since sense of experience is subjective in nature, individual differences, consisting of psychological factors such as personality, cognitive abilities, cognitive style and domain-specific knowledge, previous experience and gender can be important in experiencing presence.

Sas and O'Hare (2003) investigated the relationship between four cognitive factors (absorption, creative imagination, empathy and cognitive style) and the sense of presence experienced in a desktop VE. They concluded that participants with a creative imagination and experience in empathy had higher levels of presence. However, they did not find any relationship between gender and sense of presence. Likewise, Schuemie et al. (2005), and Skalski and Tamborini (2007) found no gender differences in the experience of presence. On the other hand, Lachlan and Krcmar (2008) found that gender differences and previous experiences with VEs affected the level of presence in computer games; men expressed more presence than women. Lombard et al. (2000) reported that women experience more presence than men when the screen sizes are increased. Alsina-Jurnet et al. (2005) and Schuemie et al. (2005) found no differences in the sense of presence with respect to the experience of 3D games and the use of computers. In addition, when Youngblut and Perrin (2002, cited in Thornson et al., 2009) examined 80 presence-related studies, they found no relationship or a negative relationship between game playing experience and presence, and between VE experience and presence.

Slater and Steed (2000) in their study assessed the relationship between presence and body movement in an immersive VE. They indicated that greater sense of presence was reported by the participants who learned the environment through body movements rather than seeing it. Likewise Dinh et al. (1999) investigated the effects of tactile, olfactory, audio cues on the participant's sense of presence in a VE. Their results indicated that there was a greater sense of presence with the addition of tactile, olfactory cues and ambient sounds. Regenbrecht and Schubert (2002), who conducted two different studies, found a significant increase in spatial presence where the participants were allowed to perform self-directed navigation with their own control on viewpoints and virtual characters. Furthermore, Schuemie et al. (2005) investigated three locomotion techniques that affected the level of presence in a VE as walk-in-place, hand-controlled viewing and gaze-directed steering. They claimed that the most natural locomotion technique, which was walk-in-place, resulted in higher levels of presence.

3.4 Previous Experience

Castel et al. (2005: 218) stated that "the ability to efficiently search the visual environment in order to locate certain objects or features is a critical component of the visual system". The previous experience of the individual, especially playing computer games and computer familiarity are the factors that can influence the attention given to certain objects or features and as a result can affect spatial updating.

3.4.1 Computer Games

Computer game experience has become a widespread activity (Green and Bavelier, 2003) that involves problem solving, planning, having skills requiring fast reflexes and superior visuomotor coordination (Spence and Feng, 2010). In computer games, the individual experiences the virtual environments from an overhead perspective or moves through 3D environments (Richardson et al., 2011). Previous studies have shown that the experience of playing computer games can influence the spatial abilities of the individuals and the virtual navigation success (Castel et al., 2005; Green and Bavelier, 2003; Quaiser-Pohl et al., 2006; Spence and Feng, 2010). Computer games are visually challenging (Green and Bavelier, 2006) and they are able to modify the processes in spatial cognition by altering the sensory, perceptual and attentional abilities of the individuals such as visual attention, visuomotor coordination and speed, tracking multiple objects and memory (Spence and Feng, 2010).

Previous research has shown that playing computer games enhance performance on tasks related to various aspects of visual attention (Castel et al., 2005; Green and Bavelier, 2003; 2006; 2007; Spence et al., 2009). Green and Bavelier (2003) demonstrated that experienced computer game players (CGPs) outperformed novice computer game players (NCGPs) on tasks measuring the spatial distribution and resolution of visual attention, the efficiency of visual attention and the number of objects can be attended. They suggested that CGPs were better at detecting information in the virtual environment.

Visuomotor coordination is the "ability to use visual information to control and direct the motor system to complete a task" (Spence and Feng, 2010: 97). Playing computer games requires visuomotor coordination; the player has to respond quickly in order to perform well in computer games. Individuals with the most computer game experience are faster and more accurate than inexperienced players (Castel et al., 2005; Dye et al., 2009a; 2009b; Richardson et al., 2011). Castel et al. (2005) demonstrated that CGPs displayed faster response times in visual attention tasks than

NCGPs. Boot et al. (2008), and Green and Bavelier (2006) showed that computer game experience is related to multiple object tracking in which CGPs are able to track objects moving at greater speed. Another aspect that is influenced by computer game playing is visual memory (Boot et al., 2008; Ferguson et al., 2008). Ferguson et al. (2008) stated that CGPs recall more objects than NCGPs and experience with computer games is associated with higher visual memory recall.

In addition to the experience with computer games, gender differences can be seen in computer game playing. Males are more experienced in activities that enhance the development of spatial skills; they play games with high spatial components such as computer games and exploratory games, and are exposed to a higher spatial experience than females (Coluccia and Louse, 2004). “Males have more extensive experience with activities that help develop spatial skills, such as model planes and carpentry and video games” (Lawton and Morrin, 1999: 75). Lawton and Morrin (1999) showed that prior experience with computer games involving navigation through virtual environment resulted in higher pointing accuracies for males since computer games were perceived as a masculine domain. It is reported that computer-related experiences, such as computer-games, computer applications (computer-aided design and drawing) and video games improve the spatial abilities of individuals (Cherney, 2008; Quaiser-Pohl et al., 2006). Quaiser-Pohl et al. (2006: 617) proposed that “individuals’ admission of playing certain types of computer games is a useful predictor of spatial abilities”, also playing computer games was seen as a boys toy and a male domain since males indicated that they played them more frequently than females. Males reported to play more computer games than do females (Barnett et al., 1997; Castelli et al., 2008; Cherney and London, 2006; Sandstrom et al., 1998;

Terlecki and Newcombe, 2005). Also, since males have more experience with computer games, they report that they have more comfort and confidence with the computer (Waller et al., 1998). Coluccia and Louse (2004) suggested that during navigation in a VE, a male advantage is enhanced due to the high familiarity with the VE among males.

The relationship between computer game experience and spatial ability revealed an advantage for males. Their results indicated that spatial ability could be developed and be improved with prior computer experience (Quaiser-Pohl et al., 2006). As a result, previous experience or training may decrease gender differences and increase individual's environmental familiarity (Chen and Stanney, 1999; Lawton and Morrin, 1999). Feng et al. (2007) suggested that in order to reduce gender differences, computer game playing may provide a reliable training regimen. Burigat and Chittaro (2007) stated that experienced users navigate significantly better than inexperienced users in a VE due to the familiarity with navigation in a 3D environment. Waller (2000) stated that the ability to navigate through different interfaces and the ability to do them automatically represents a potential interfering factor resulting in males having greater experience in the use of computer and computer games than the females. In order to eliminate the differing ability, a training phase with the VE apparatus before the experimental session is provided (Castelli et al., 2008; Tlauka et al., 2005). Although interface proficiency, which is the individual's ability to use the keyboard keys to navigate through the simulation (Tlauka et al., 2005), is one of the predictors of learning in VEs (Waller, 2000), Tlauka et al. (2005) stated that initial training with the keyboard keys to navigate did not significantly associate with performance in the spatial tests.

Females are generally slower than males when navigating (Lin et al., 2012; Moffat et al., 1998; Sandstrom et al., 1998; Saucier et al., 2003). Sandstrom et al. (1998) demonstrated that females were significantly slower than males at completing a pre-testing obstacle course that was intended to familiarize subjects with the VE and test for any pre-existing differences in joystick ability or perception of the environment. Likewise, Tlauka et al. (2005) indicated that females needed more time to travel from the start to the finish when following a route through a simulated shopping centre.

3.4.2 Computer Familiarity

With the increase in computer usage, it has become important to understand the relationship between technology and human behavior. Three constructs have been identified as a result of these interaction: computer aversion or anxiety, attitudes towards computers and experience with computers (computer familiarity) (Schulenberg and Melton, 2008; Schulenberg et al., 2006). Computer anxiety is a psychological phenomenon (Beckers and Schmidt, 2001) that is defined as a negative emotional state experienced during computer use or imagining future computer use (Bozionelos, 2001). Computer anxiety has also been referred to as aversion to computer, fear or apprehension towards dealing with computers and points out negative feelings (Beckers et al., 2006; Schulenberg and Melton, 2008; Schulenberg et al., 2006; Tekinarslan, 2008; Teo, 2008). Bozionelos (2001) found that students with a high level of computer anxiety tend to avoid computer or general areas where computers are found, are cautious with computers, possess negative feelings about computers and shorten the use of computers.

The most consistent correlate of computer anxiety is computer experience (Bozionelos, 2001). Computer experience is defined as the degree to which a person understands how to use a computer (Beckers and Schmidt, 2003). Smith et al. (1999. cited in Garland and Noyes, 2004) stated that computer experience as measured by computer use and ‘the computer experience’ should be differentiated. They referred to these terms as objective and subjective measures of computer experience, respectively. Researchers have focused on the objective measures of computer experience that is computer use. It is usually measured by asking participants how many years they have used a computer and for how many hours a week (Garland and Noyes, 2004). Smith et al. (1999) identified three measurable components of objective computer experience: amount of computer use, which examines the amount or accumulative use of computers over time, opportunity to use computers, which reflects the availability of computer resources that facilitate computer use across a number of settings, and diversity of experience, which examines individual differences in the utilization of a variety of computer software packages (Smith et al., 2000). Variables such as computer usage level, usage frequency, computer ownership, computer education, and amount and breadth of time in computer usage are used as indicators of computer experience (Bozionelos, 2004; Gürcan-Namlu and Ceyhan, 2003; Tekinarslan, 2008). It has been stated that increased computer experience and frequent usage of computer leads to lower levels of computer anxiety (Beckers and Schmidt, 2003; Bozionelos, 2004; Gürcan-Namlu and Ceyhan, 2003; Tekinarslan, 2008).

Attitudes towards computers are cognitive in scope and are defined as positive or negative thoughts that individuals have about computers, their utility and their role in society (Schulenberg and Melton, 2008; Schulenberg et al., 2006). Computer attitudes can affect individual behaviors and this will influence the individual's use of computers (Garland and Noyes, 2004). Smith et al. (1999: 241, cited in Garland and Noyes, 2004) defined subjective computer experience as "specific feelings or emotions that are engendered by computer-related stimuli". With respect to Smith et al. (1999), Garland and Noyes (2004) stated that an individual's attitude is determined by the feelings towards computers. Computer attitudes correlate positively with computer experience (Garland and Noyes, 2004; Smith et al., 1999). The more experience an individual has with computers the more likely they are to express positive attitudes (Bozionelos, 2001; Garland and Noyes, 2004; Teo, 2008).

Computer aversion, attitudes towards computers and computer experience are related constructs (Schulenberg et al., 2006), in order to assess these constructs various measures have been identified for each construct separately. However, the index developed by Schulenberg et al. (2006) assessed the three computer related constructs in a single measure referred to as the Computer Aversion, Attitudes and Familiarity Index (CAAFI). The CAAFI is comprised of 30 items with 10 items in each construct (aversion, attitude and familiarity) (see Appendix B). The CAAFI utilizes a 7-point Likert scale that ranges from -3 (absolutely false) to 3 (absolutely true). The items are positively and negatively worded and when they are summed, higher positive scores indicate less computer aversion, more favorable computer-related attitudes and greater familiarity (Schulenberg and Melton, 2008).

In the next chapter, the methodology of the study is defined and a model for vertical navigation is formulated by identifying the participants and the VE. In addition, the instruments and software that are related to the study are specified.

CHAPTER 4

METHODOLOGY

4.1 Aim of the Study

Architectural design is a problem solving activity that requires experiencing the spatial layout of a building, discovering local architectural cues and maintaining spatial orientation during navigation. Navigation can be problematic when the environment is complex or unfamiliar. People have to rely either on their previous experience with similar environments or on the local architectural cues they encounter while navigating.

Soeda et al. (1997, cited in Hölscher et al., 2006) found that people lost their orientations due to vertical circulation and as a result their performance decreased in tasks involving vertical level changes. They also identified another challenge in multi-level buildings in which people assumed that the typology of the floor plans were identical at different levels. Various fields, such as psychology and cognitive science have examined vertical circulation by focusing on the qualitative properties of the term and on individual factors, but this study aims to examine vertical navigation with respect to local architectural cues from an interior architectural perspective and at the end propose a guideline for interior architects. Since different local architectural cues within an environment can influence navigation and spatial orientation, interior architects need to consider how local architectural cues are utilized during vertical navigation and how they affect spatial reasoning in the architectural decision making process. From the view of an interior architect, the geometric attributes can be configured in the design process, but with the desktop VE, the geometric attributes of the local architectural cue can be varied systematically in order to understand their influence on vertical navigation.

This study aims to provide an understanding how local architectural cues, especially staircases are utilized during vertical navigation and how they affect the individual's vertical navigation behavior in a novel multi-level desktop VE. It focuses on the geometric attributes of the staircases by altering the angle between the cue directions in a cue pair from observation point while keeping the other geometric attributes constant. The research issues consist of the geometric attributes of the staircases and their relation with gender, sense of direction, sense of presence, computer familiarity, and previous computer experience within the desktop VE.

4.2 Research Questions

1. Is there a difference in preference for ascending and descending staircases in the VE?

    a) In a VE with a 90° difference between the cue pairs (Set 1)

    b) In a VE with a 180° difference between the cue pairs (Set 2)

2. Is there a relationship between gender and the staircase preferences in the VE?

a) In a VE with a 90° difference between the cue pairs (Set 1)

b) In a VE with a 180° difference between the cue pairs (Set 2)

3. Is there a relationship between the navigational abilities and the staircase preferences in the VE?

a) In a VE with a 90° difference between the cue pairs (Set 1)

b) In a VE with a 180° difference between the cue pairs (Set 2)

4. Is there a difference between a cue pair of a 90°difference and a 180° difference with respect to the virtual navigation?

a) Circulation path

b) Staircase preference

c) Virtual navigation total duration

4.3 Hypotheses

1. There is a significant difference in preference for ascending and descending staircases in the VE.

2. There is a significant relationship between gender and the staircase preferences in the VE.

3. There is a significant relationship between the navigational abilities and the staircase preferences in the VE.

4. There are significant differences between a cue pair of a 90° difference and a 180° difference with respect to the circulation path, staircase preferences and virtual navigation total duration.

4.4 The Proposed Model

The proposed model integrates the participant and the VE with respect to the local architectural cues of the spatial environment during vertical navigation in a desktop VE (see Figure 7).

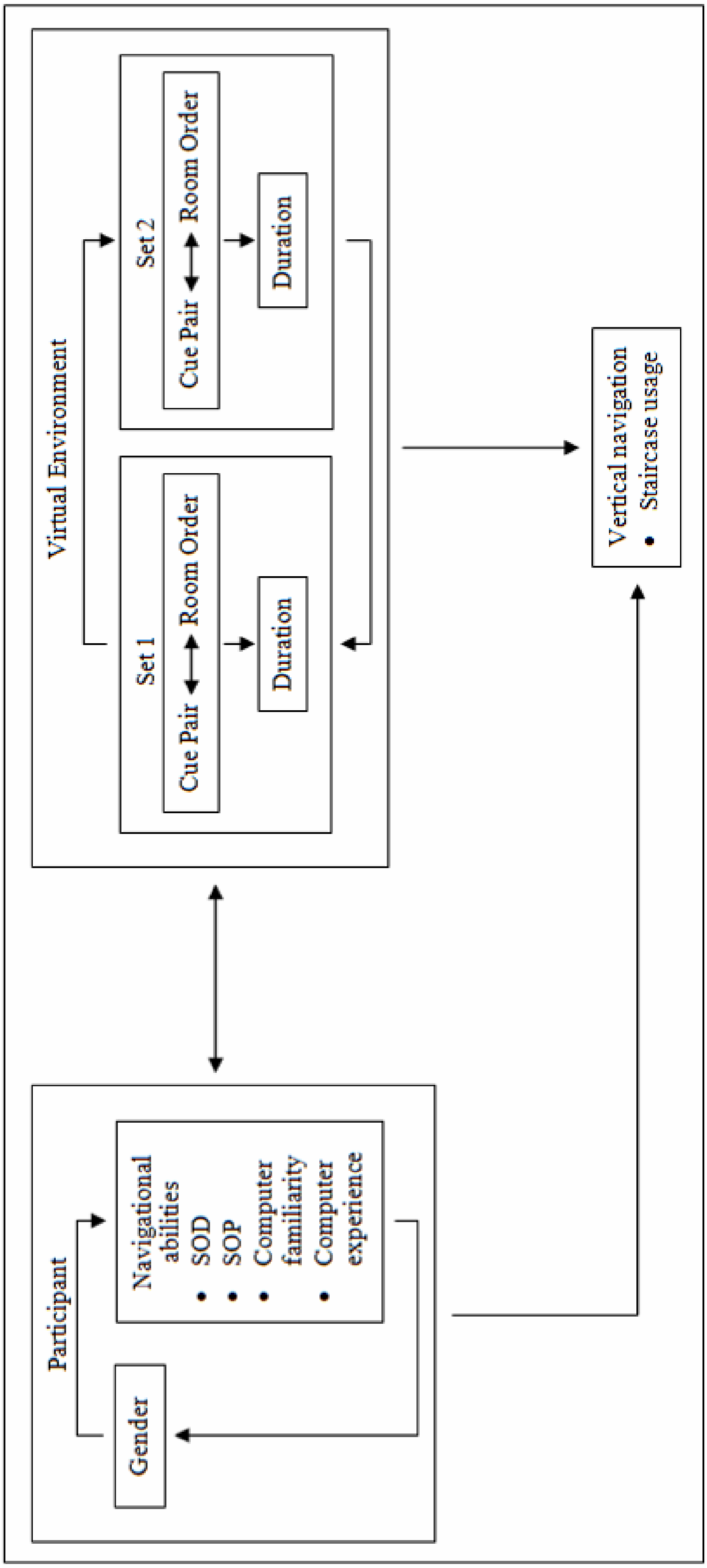

Figure 7. Proposed model for vertical navigation

Local architectural cues, such as staircases, halls, corridors and openings, can influence the navigation performance of the individual. The geometric attributes of a staircase can be defined as (Figure 8):

- the distance from the cue to observation point of the participant (D),
- the width of the cue (W),
- the height of the cue (H),
- the place of the cue with respect to the participant's view direction (Left (L) or Right (R)),
- the angle between the view direction and the cue (A1), and
- the angle between the view direction and the cue direction (A2).

'View direction' can be defined as the facing orientation of the participant, in other words, the direction of the participant's view from his/her current position in which his/her head and body are in a straight line. 'Cue direction' is the direction of the cue.

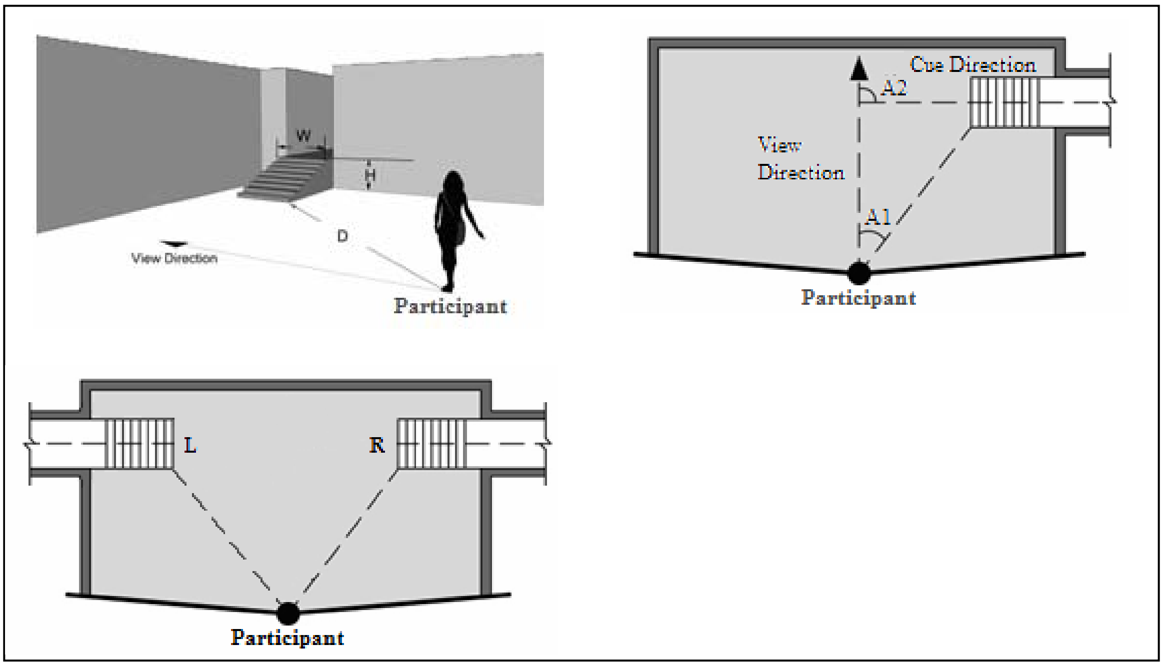

Figure 8. Attributes of D, W, H, A1, A2, L and R of Staircase (Adapted from Sun et al., 2008: 6)

4.4.1 Participants

With respect to the model, gender differences and navigational abilities that consist of sense of direction (SOD), sense of presence (SOP), computer familiarity and computer experience are two constitutes of the participant. Gender differences shape a participant's navigational abilities and in turn, navigational abilities influence gender, for example some female participants may have good sense of direction (GSOD), whereas others may have poor sense of direction (PSOD). Each of the navigational abilities is identified with separate questionnaires and each participant differs in his/her navigational abilities. In addition to the interaction between the two constitutes of the participant, the navigation behavior of the participant within the virtual environment can also be influenced by the two constitutes.

4.4.2 Virtual Environment

Environments can be categorized as vista or environmental spaces. Vista spaces can visually be apprehended from a single viewpoint without locomotion, whereas environmental spaces require the individual to move from one location to another in order to perceive the whole space (Hegarty et al., 2002). The latter requires the individual to spatially update her/his current position with respect to her/his previous position.

The desktop VE contains 2 environmental spaces (referred to as Set 1 and Set 2) that consist of 2 staircases each as the local architectural cues. In Set 1, the staircases, which are the cue pairs, are positioned perpendicular to each other, in other words, the angle between the cue directions is 90°. In Set 2, the angle between the cue directions is 180°.

In the VE, the participants have complete control over their movements in the VE; this is referred to as continuous specification. The participants navigate from a first-person perspective and they are able to navigate in the VE by utilizing the arrows on the keyboard and the mouse for the direction of their viewpoint. During the virtual navigation, gender differences and navigational abilities have an effect on the staircase preferences, circulation order, i.e. the order of room visits, and navigation duration. Each participant differs in his/her preferences in the VE. The interaction between the participant and the VE leads to vertical navigation in which the participants indicate their reasons for choosing a staircase for ascending and descending in the desktop VE.

While navigating in the VE, the utilization of a cue within the cue pair affects the order of room visits, for example, choosing a specific cue for ascending influences the order of room visits on the first floor of the VE, likewise the order of room visits influences the utilization of a cue for ascending and descending. As a result, this determines the navigation duration and vertical navigation. The interactions within Set 1 and Set 2 are compared in order to understand which cue is efficient during vertical navigation in the VE.

4.5 Instruments and Software

4.5.1 Santa Barbara Sense of Direction Scale (SBSOD)

The SBSOD questionnaire consists of 15 items on a 1-7 Likert scale containing 8 positive and 7 negative statements about spatial and navigational abilities, navigational aptitudes and experience (see Appendix A). Once the scores on the items containing positive statements are inverted, the total score is calculated by totaling the individual scores. A low score corresponds to a greater sense of self perceived direction (Hegarty et al., 2002).

4.5.2 Computer Aversion, Attitudes and Familiarity Index (CAAFI)

The CAAFI is comprised of 30 items that help to better understand computer aversion, attitudes toward computers and computer familiarity (Schulenberg and Melton, 2008) (see Appendix B). The CAAFI utilizes a 7-point Likert scale that ranges from -3 (absolutely false) to +3 (absolutely true). It contains positively and negatively worded items with some items needing reverse scoring. When the items are summed, a high positive score indicates less computer aversion, more favorable computer-related attitudes and greater familiarity (Schulenberg and Melton, 2008).

4.5.3 Igroup Presence Questionnaire (IPQ)

The IPQ is a scale for measuring the sense of presence experienced in the VE that consists of 14 items rated on a 7 point rating scale that ranges from -3 to 3 (Schubert et al., 2001) (see Appendix D). It consists of 1 general item, 5 items for 'spatial presence', 4 items for 'involvement' and 4 items for 'realness'. The general item that assesses the general 'sense of being there' has high loadings on the 3 factors with a strong loading on 'spatial presence' (Igroup, 2008). When scoring, all the items have a range from 1 to 7, but there are 3 items that are reversed. By answering the items, the spatial presence of the participants was verified.

4.5.4 Observation Sheet and Computer Experience Questionnaire

An observation sheet was developed in order to record the virtual navigation of the participants (see Appendix C). It comprises of the participants characteristics that consist of the participant's name, age, gender and handedness (left-right handed), and the virtual navigation characteristics. The order of the room visits on the ground and first floors, the preferred ascending and descending staircases, the reason for the preference and navigation durations are recorded separately for Set 1 and Set 2.

The computer experience questionnaire was developed in order to understand the participant's knowledge about Second Life, their ability to play computer games, frequency of playing computer games, years of playing computer games and the types of computer games they played (see Appendix D). The computer experience questionnaire was different from the CAAFI since the CAAFI did not assess these variables.

4.5.5 Second Life

Second Life is a computer-simulated 3D environment that is elaborated by the participation of its users. Users are able to interact in the environment with an avatar. The avatar, which is the visual representation of the user, is manipulated with a keyboard and a mouse. Second Life enables real-time interactions and offers its users the possibility to build virtual spaces and objects, and personify their avatars through a user-friendly interface (Hendaoui et al., 2008). Users are able to navigate by walking, flying and teleporting between spaces and other movement types such as jumping and running are available. Users are able to view the 3D environment through the avatar, i.e. first-person viewpoint, or over the avatar, i.e. third-person viewpoint in which they see the avatar. Navigation in Second Life is controlled by the keyboard and the direction of view is changed by the mouse.

In the next chapter, an experiment was conducted in order to understand the staircase preferences during vertical navigation within the desktop VEs. The participants, VEs and procedure were defined with respect to the methodology.

CHAPTER 5

THE EMPIRICAL RESEARCH

5.1 The Experiment

5.1.1 Participants

The participants consisted of undergraduate students from the 2009-2010 academic year in the department of Interior Architecture and Environmental Design (IAED) at İhsan Doğramacı Bilkent University. One hundred and eighty senior students were chosen randomly according to gender from the 4th year 'Interior Design' studio with cluster sampling. As 4th year students they were familiar with computer-based environments due to the computer-based courses that they took during the second and third years of their education and had sufficient design education background. There were an equal number of female and male participants whose age range was from 18 to 34 with a mean age of 22.39 years (SD = 2.17). The majority were right-handed with only 13 left-handed participants. The participants were randomly assigned to the experimental conditions.

5.1.2 Procedure

5.1.2.1 Phase I: Pre-test Questionnaire

The study was conducted in three phases. In the first phase, two questionnaires were administered; the Santa Barbara Sense of Direction Scale (SBSOD) and the Computer Aversion, Attitudes and Familiarity Index (CAAFI) (see Appendices A and B, respectively). According to the SBSOD results of the 180 participants, participants below the mean were grouped as having 'good' sense of direction (GSOD) and those who were above the mean were grouped as having 'poor' sense of direction (PSOD). In the CAAFI, items related to computer familiarity were considered in the study in order to assess the participants' familiarity with the computer. According to the computer familiarity results of the 180 participants, participants below the mean were grouped as 'poor' and those who were above the mean were grouped as 'good'.

5.1.2.2 Phase II: Testing on Computer

In the second phase, the gender-wise distributed participants were seated at the computer and tested individually. They navigated the desktop VE from an egocentric reference frame by either utilizing the up-down-right-left arrows or the 'W', 'A', 'S' and 'D' keys for walking and the mouse for changing their point of views. The VE was a three-dimensional 2 storey high building that was designed in Second Life. Each participant was given 3 minutes to acquaint themselves with the keyboard and mouse within the Second Life environment. They navigated in an open environment to become familiar with the virtual world.

There were 2 sets of design spaces; each set tested the differences in the angles between the cue directions in a cue pair from the observation point. Each design space, which was 21m x 35m x 7.8m, consisted of 2 staircases; the angles between the cue directions were 90° and 180°, respectively. In the design space, there were 6 rooms; 3 on the ground floor, 3 on the first floor and 2 staircases. In the first set (Set 1), the staircases were located in the middle and on the left side of the entrance; the angle between the cue directions was 90° (see Figure 9). In the second set (Set 2), the 2 staircases were located on both sides of the entrance; the angle between the cue directions was 180° (see Figure 10).

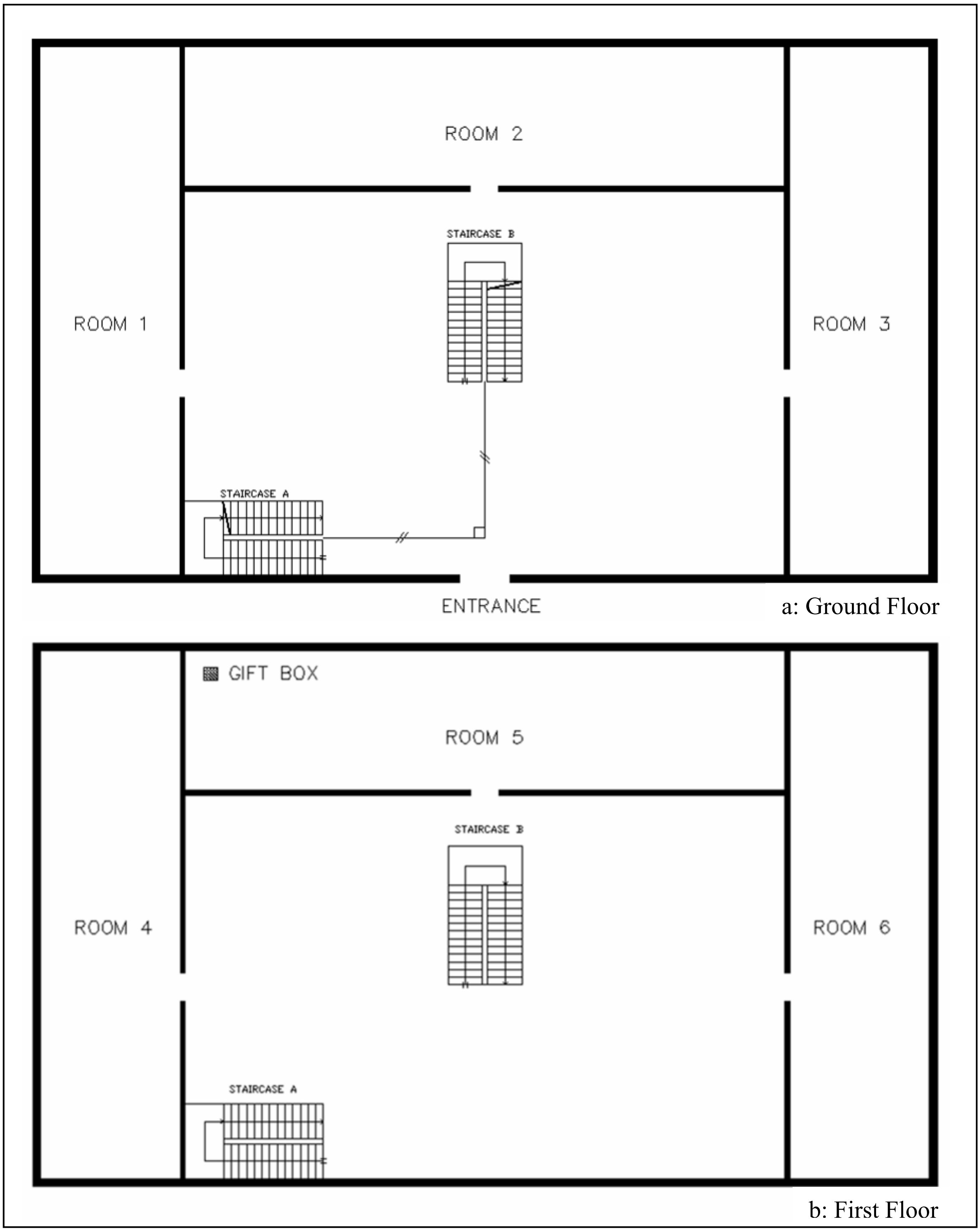

Figure 9. Set 1: An angle difference of 90° between the cue pair (a: Ground floor, b: First floor)

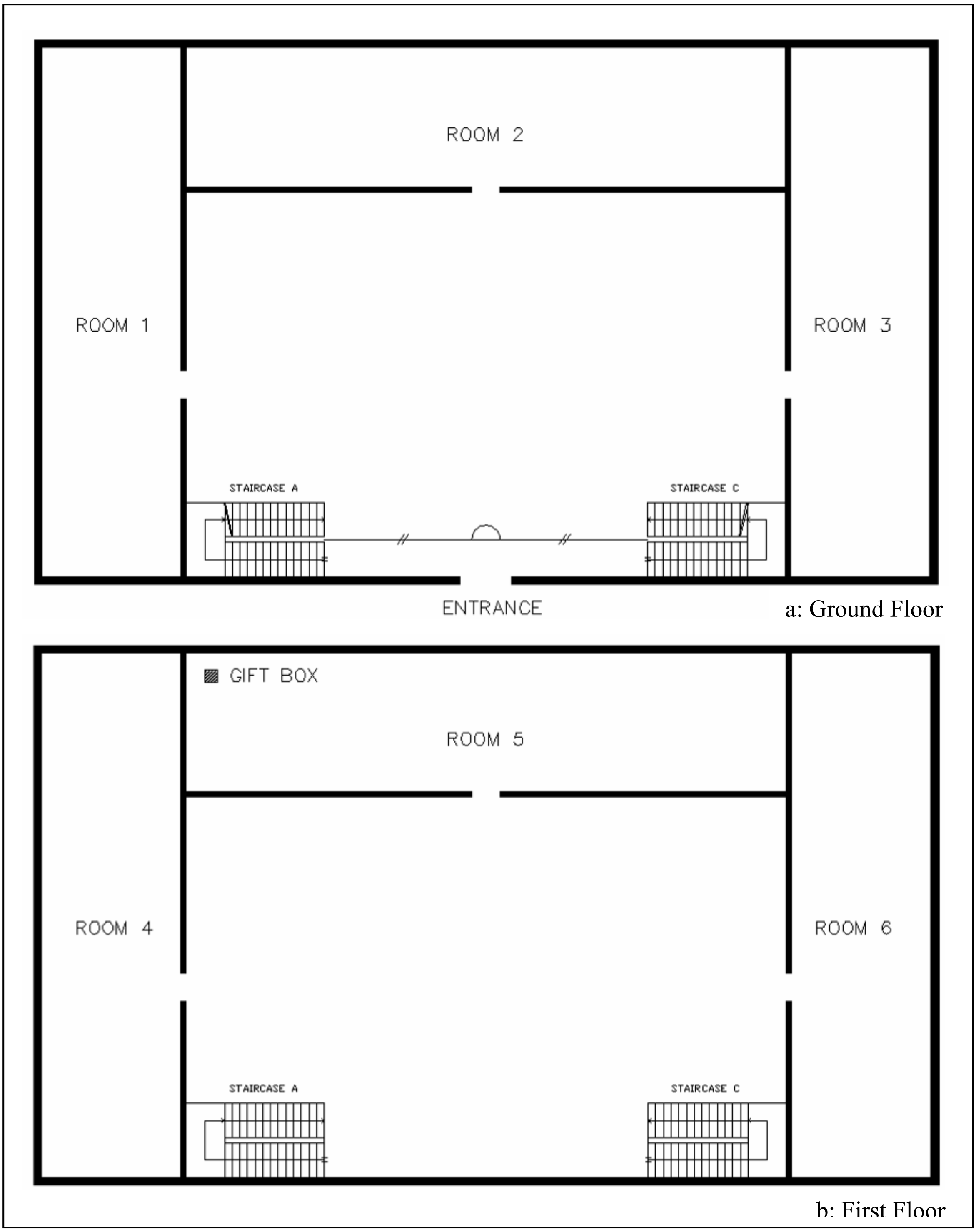

Figure 10. Set 2: An angle difference of 180° between the cue pair (a: Ground floor, b: First floor)

In Set 1, the participants could view the two staircases at the same time (see Appendix F, Figure F2) due to the binocular field of view that covers a region of about 120° (Henson, 1993, cited in Jansen, 2012); however, in Set 2, the locations of the two staircases exceeded the binocular field of view of 120° (see Appendix F, Figures F16-F19). To eliminate any biases in staircase preferences that were formed at the entrance, the participants were told to visit all the rooms until they found a gift box. A gift box, which was distinguishable from the surrounding (Figure 11), was placed on the first floor in the middle room (see Figures 9b and 10b; Room 5).

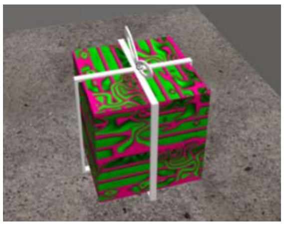

Figure 11. Gift box

To eliminate the effect of color in the experiment, the interior of the VE and the staircases were between the black-white scale (see Appendix F). The width and height of the staircases and the distance from the staircases to the observation point were kept constant.

The participants were told to explore the ground floor and then the first floor, get the gift box and return back to the entrance. Two independent samples, each consisting of 90 participants (45 females and 45 males) alternately navigated the 2 sets with the angle differences of 90° and 180° between the cue pairs. While navigating in the VE, each participants' circulation path, staircase preference and their reasons, navigation durations on the ground floor and first floors, and the virtual navigation total durations (i.e. starting and ending at the entrance after bringing the gift box to the entrance) were recorded separately for Set 1 and Set 2 (see Appendix C). For both sets, 6 alternative routes for the ground floor and 5 alternative routes for the first floor were identified as the circulation paths (see Table 2). Participants could navigate the rooms of the ground and first floors in any order. Since the gift box was located in the middle room of the first floor, participants had the chance of directly choosing the middle room before visiting the other rooms of the first floor. After finding the gift box they did not visit the other rooms, but went directly to the entrance.

Table 2. Alternative circulation paths of room visits for both sets in the VE

	Order of the Rooms Visited	
Alternatives	Ground Floor	First Floor
1	1 – 2 – 3	4 – 5
2	1 – 3 – 2	4 – 6 – 5
3	2 – 1 – 3	5
4	2 – 3 – 1	6 – 4 – 5
5	3 – 1 – 2	6 – 5
6	3 – 2 – 1	

For the staircase preferences, 4 alternative routes were determined for both sets in the VE (see Table 3). Participants could either utilize the same staircase for ascending and descending or the reverse (i.e. one for ascending and the other for descending).

Table 3. Staircase preferences for both sets in the VE

	Staircase Preferences	
Alternatives	Set 1	Set 2
1	A – A	A – A
2	A – B	A – C
3	B – A	C – A
4	B – B	C – C

5.1.2.3 Phase III: Post-test Questionnaire

In the third phase, after navigating in the VE, presence and computer experience questionnaires were administered in order to assess the participants' sense of presence within the VE and prior experience with the computer (see Appendix D). The assessment of sense of presence was important because the participants had to feel present in order to orient themselves.

In the first part, the participants rated their level of presence in the VE by answering the questions in the 'Igroup Presence Questionnaire' (IPQ). The last part aimed to identify the participants' familiarity with Second Life and their ability to play computer games. In addition, they indicated how often they played computer games and the game types (see Appendix D).

Three separate pilot studies were conducted. The first pilot study was carried out with 8 participants to test the clarity of the questionnaires, and the usability and design of the building in the VE. The next 2 pilot studies, which were done with 4 participants each, detailed the design of the virtual building. These participants were not included in the experiment.

5.2 Results

Statistical Package for Social Sciences (SPSS) 15.0 was used to analyze the data. In the analysis of the data, frequency tables, chi-square tests, independent t-tests, correlated t-tests and ANOVA were used.

5.2.1 Related to the Staircase Preferences within each VE

In each VE, the staircase preferences were examined by focusing on the ascending and descending preferences, and ascending preferences according to the first and last visited rooms. They were assessed by correlated t-tests, chi-squares, ANOVA and independent t-tests.

5.2.1.1 Related to the Ascending and Descending Preferences of the Staircases within each VE

The staircase preferences for ascending and descending were assessed within each VE with the cue pairs by using a correlated t-test. In the VE with a 90° difference between the cue pairs (Set 1), there was no significant difference between the ascending and descending staircases (M = 1.63, SD = 0.49 and M = 1.67, SD = 0.47, respectively; see Appendix E, Table E1) and there was no correlation between the ascending and descending staircases (see Appendix E, Table E2).

For the VE with a 180° difference between the cue pairs (Set 2), the two means did not differ significantly (M = 1.93, SD = 1.00 and M = 2.18, SD = 0.99, respectively; see Appendix E, Table E3). However, the correlation test showed that there was a positive low relationship ($r = 0.24$, $df = 88$, $p < 0.024$) between the ascending and descending staircases.

5.2.1.2 Staircase Preferences for Ascending according to the First Visited Room

In Set 1, there was no significant relationship between the first visited room on the ground floor circulation path and the staircase preference for ascending (see Appendix E, Table E4). However, for Set 2, there was a significant relationship between the first visited room of the ground floor circulation path and the staircase preference for ascending ($\chi^2 = 15.82$, $df = 2$, $p = 0.000$).

The uncorrelated analysis of variance (ANOVA) test was conducted to find if the staircase preferences for ascending according to the first visited room on the ground floor had different means in Set 2. The effect of the first visited room was significant overall ($F_{2,87} = 9.28$, $p = 0.000$). When a Bonferroni adjustment was made for the number of comparisons, there was no significant difference between the means of

Room 1 and Room 2 (see Appendix E, Table E5); however, there were two significant differences. The mean of Room 1 (M = 2.65, SD = 0.79) was significantly higher (t = 4.33, df = 61, two-tailed p = 0.000) than that of Room 3 (M = 1.57, SD = 0.91) and the mean of Room 2 (M = 2.11, SD = 1.01) was significantly higher (t = 2.37, df = 71, two-tailed p = 0.020) than that of Room 3 (M = 1.57, SD = 0.91).

In order to understand which staircase for ascending was preferred during the virtual navigation according to the first visited room on the ground floor in both sets, an independent t-test was conducted. In Set 1, there was no significant difference between Staircase A and Staircase B (see Appendix E, Table E6). However, in Set 2, the mean preference of Staircase A (M = 2.63, SD = 0.61) was significantly higher (t = 4.33, df = 88, two-tailed p = 0.000) than that of Staircase C (M = 1.98, SD = 0.81).

5.2.1.3 Staircase Preferences for Ascending according to the Last Visited Room

In Set 1, there was not a significant relationship between the last visited room on the ground floor circulation path and the staircase preference for ascending (see Appendix E, Table E7). However, for Set 2, there was a significant relationship between the last visited room on the ground floor circulation path and the staircase preference for ascending (χ^2 = 8.51, df = 2, p = 0.014).

The uncorrelated analysis of variance (ANOVA) test was conducted to find if the staircase preferences for ascending according to the last visited room on the ground floor had different means in Set 2. The effect of the last visited room was significant overall ($F_{2,87} = 4.54$, $p = 0.013$). When a Bonferroni adjustment was made for the number of comparisons, the only significant difference was between the means of Room 1 and Room 3 ($t = -2.67$, $df = 81$, two-tailed $p = 0.009$). The mean of Room 3 ($M = 2.27$, $SD = 0.98$) was significantly greater than that of Room 1 ($M = 1.68$, $SD = 0.96$). There were no significant differences between the means of Room 1 and Room 2 and between Room 2 and Room 3 (see Appendix E, Tables E8 and E9, respectively).

An independent t-test was conducted in order to understand which staircase for ascending was preferred during the virtual navigation according to the last visited room on the ground floor in both sets. In Set 1, there was no significant difference between Staircase A and Staircase B (see Appendix E, Table E6). However, in Set 2, the mean preference of Staircase C ($M = 2.02$, $SD = 0.95$) was significantly higher ($t = -2.70$, $df = 88$, two-tailed $p = 0.007$) than that of Staircase A ($M = 1.50$, $SD = 0.85$).

5.2.1.4 Summary of Staircase Preferences

Table 4 depicts a summary of the ascending and descending preferences of the staircases, and the staircase preferences for ascending according to the first and last visited rooms within each set (see Table 4).

Table 4. Staircase preferences – ascending and descending within each VE

		Set 1	Set 2
Staircase Preferences - Ascend	Descend	No Correlation	Low (+) Correlation
	1st Room - Ground flr.	No Correlation	Room 1 > Room 3 < Room 2
	Last Room - Ground flr.	No Correlation	Room 3 > Room 1 *Room 1 = Room 2, Room 2 = Room 3*
	Stair. pref. acc. to 1st Room - Ground flr.	A = B	A > C
	Stair. pref. acc. to Last Room - Ground flr.	A = B	A < C

5.2.2 Related to Gender Differences within the Experiment

In each experiment set, there were 90 participants with an equal number of female and male participants. The gender differences were examined with respect to sense of direction, sense of presence, computer familiarity, computer experience and properties of the virtual navigation, i.e. first visited room, staircase preferences and virtual navigation total durations within Set 1 and Set 2.

5.2.2.1 Gender Differences and Sense of Direction

According to the results of the SBSOD questionnaire, the mean score was 3.43 (SD = 0.90). Participants, who were below the mean, were grouped as having 'good' sense of direction (GSOD) and those who were above the mean were grouped as having 'poor' sense of direction (PSOD). More than half of the male participants

(57 participants) revealed to have GSOD, whereas only 38 female participants had GSOD (Figure 12).

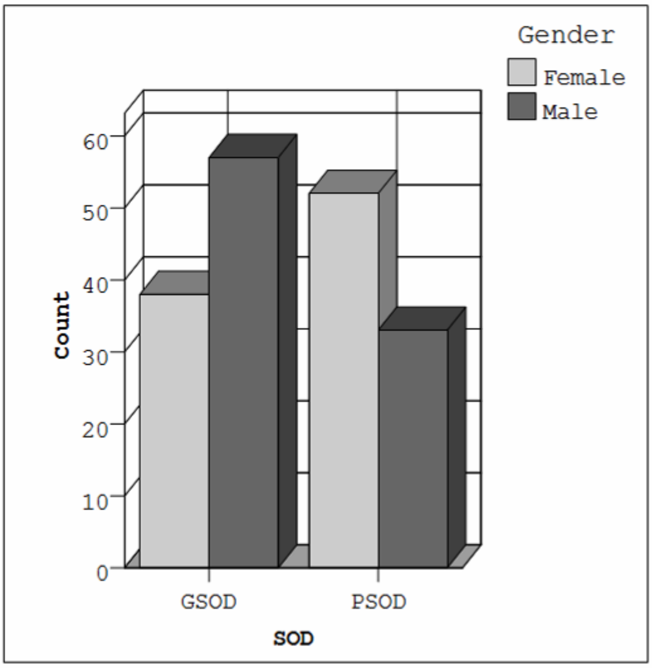

Figure 12. Distribution of sense of direction results according to gender

Chi-square analysis was used to assess if the sense of direction groups were independent from gender for the sets separately. According to the chi-square test, there was a significant relationship between gender and the scores obtained from the SBSOD questionnaire for Set 1 ($\chi^2 = 5.42$, df = 1, p = 0.020); however, there was no significant relationship between gender and the scores obtained from the SBSOD questionnaire for Set 2 (see Appendix E, Table E10).

In order to test whether the means of the SBSOD questionnaire for female and male participants were different, an independent t-test was conducted. According to the independent t-test, there was a significant difference in gender with respect to sense of direction. In Set 1, the mean sense of direction scores of female participants (M = 1.58, SD = 0.50) was significantly higher (t = 2.38, df = 88, two-tailed p = 0.020) than that of male participants (M = 1.33, SD = 0.48).

5.2.2.2 Gender Differences and Sense of Presence

In the IPQ, the participants rated the general item and the 3 factors of ‘spatial presence’, ‘involvement’ and ‘realness’ as 5.17 (SD = 1.40), 4.58 (SD = 0.92), 3.74 (SD = 1.10) and 3.43 (SD = 0.83), respectively. For the general item and the 3 factors, scores were classified according to the mean score as below (P) and above the mean (G). The mean (M) and standard deviation (SD) values of the IPQ factors for each gender is depicted in Table 5. Male participants evaluated the factors except for the ‘involvement’ factor higher than the female participants.

Table 5. Group statistics for gender and IPQ

	General Item		Spatial Presence		Involvement		Realness	
Gender	M	SD	M	SD	M	SD	M	SD
Female	5.07	1.43	4.56	1.00	3.87	1.19	3.41	0.89
Male	5.27	1.36	4.60	0.84	3.61	0.99	3.45	0.77

According to this classification, 133 participants rated the general item as having themselves a good sense of ‘being there’ in the VE. For the factors ‘spatial presence’ and ‘realness’, 97 of the participants felt present in the VE and indicated the VE to be consistent with the real world, in addition, 95 participants indicated that they were aware of the VE (see Appendix E, Table E11).

Chi-square analysis indicated that there were no significant relationships between gender and the factors of the IPQ for Set 1 and Set 2 (see Appendix E; Tables E12-E15). As a result gender was independent from the IPQ in Set 1 and Set 2.

5.2.2.3 Gender Differences and Computer Familiarity, and Computer Experience

The mean score for the computer familiarity factor of CAAFI was 5.46 (SD = 12.28) and the range was from -30 to 29. Participants were grouped into two categories according to the mean score as below (poor) and above the mean (good). More than half of the male participants indicated good computer familiarity (GCF), whereas the majority of the female participants indicated poor computer familiarity (PCF) (Figure 13). Overall 51.67% of the participants had good familiarity with the computer.

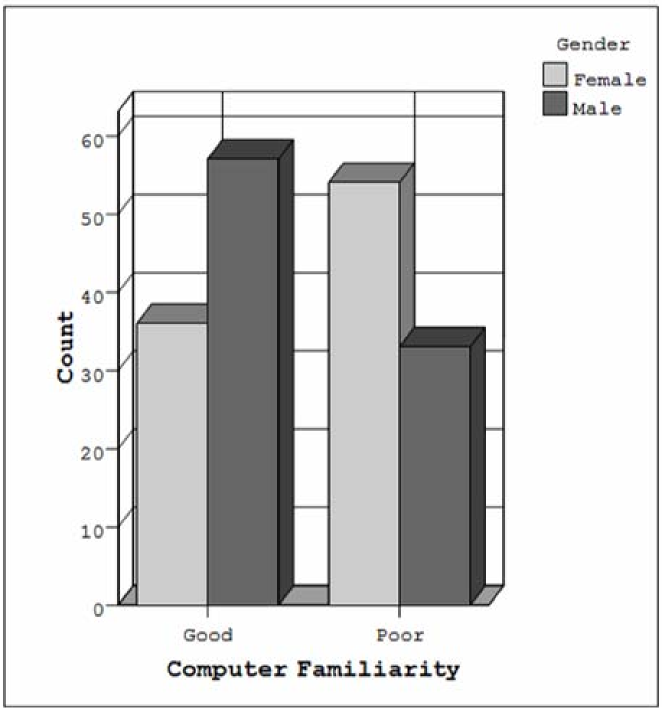

Figure 13. Distribution of computer familiarity results according to gender

Table 6 depicts the distribution of the participants according to gender, sense of direction and computer familiarity within each set. According to the distribution, the majority of the female participants with a PSOD expressed their computer familiarity as being poor; however, this was the reverse for the male participants in both sets.

Table 6. Distribution of sense of direction and computer familiarity scores within each set according to gender

		Computer Familiarity in Set 1			Computer Familiarity in Set 2		
Gender	Sense of Direction	PCF	GCF	Total	PCF	GCF	Total
Female	GSOD	12	7	19	10	9	19
	PSOD	18	8	26	14	12	26
Male	GSOD	6	24	30	13	14	27
	PSOD	4	11	15	10	8	18

To determine if there was a significant relationship between gender and the scores obtained from the computer familiarity questionnaire, chi-square tests were conducted for the sets separately. Chi-square analysis indicated that there was a significant relationship between gender and the scores obtained from the computer familiarity questionnaire for Set 1 ($\chi^2 = 18.00$, df = 1, p = 0.000); however, there was no significant relationship between gender and the scores obtained from the computer familiarity questionnaire for Set 2 (see Appendix E, Table E16).

According to the independent sample t-test, there was a significant difference between gender and computer familiarity in Set 1. The mean computer familiarity scores of female participants (M = 1.67, SD = 0.48) was significantly higher (t = 4.69, df =88, two-tailed p = 0.000) than that of male participants (M = 1.22, SD = 0.42).

In the computer experience results, 80 participants out of 180 indicated that they heard about SL, but only 26 participants used SL before and they mainly used it once. One hundred and fifty participants played computer games and they either played them less than once in a week (31.7%) or more than once in a week (32.2%). The mean year for playing computer games was 11.70 years (SD = 4.06). The years for playing computer games were grouped into 4 categories as: 1-9 years, 10-11 years, 12-14 years and 15-22 years (Figure 14).

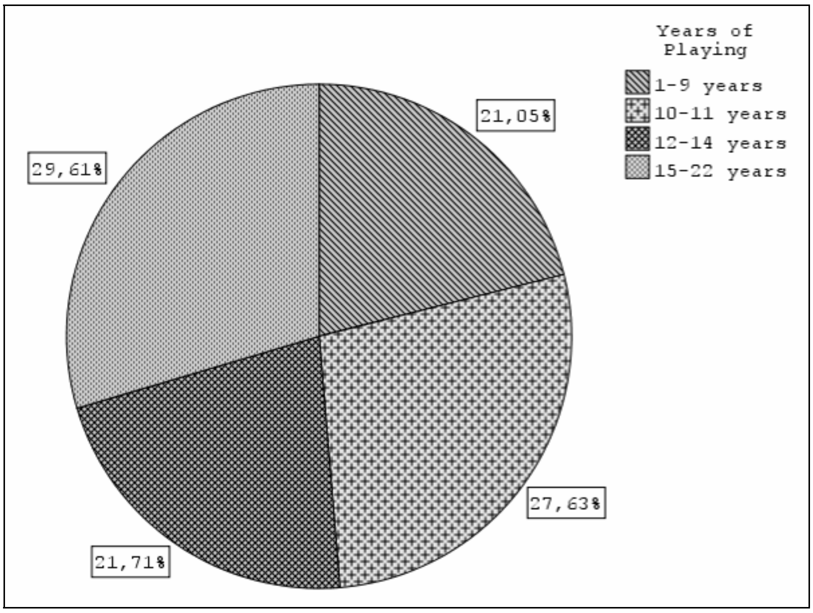

Figure 14. Distribution of years of playing computer games

This classification was formed according to the 25th, 50th and 75th percentiles. An even distribution between the years was not unconsidered since statistical analysis could not be done. Twelve genres for computer games were identified from the responses of the participants; these were strategy, role-playing, shooting, sports, racing, action and adventure, fighting, simulation, puzzle, platformer, arcade and playstation, but only the 'shooting' genre was considered in the evaluation since the view point of the participant, which was first person point of view, the structure of the environment in the shooting games, and the usage of the keyboard and mouse couple were similar to the environment in the VE. According to the specified computer game genre, participants were grouped as whether or not they played this genre. Out of 150 who played computer games only 64 participants played 'shooting' games.

To determine if computer experience was independent from gender, chi-square tests were conducted for Set 1 and Set 2. In Set 1, there was a significant relationship between gender and playing computer games ($\chi^2 = 4.87$, df = 1, p = 0.027). There was a significant relationship between gender and frequency of playing computer games ($\chi^2 = 16.97$, df = 2, p = 0.000). In addition, there were significant relationships between gender and playing computer games in years, and between gender and playing games with a shooting genre ($\chi^2 = 30.06$, df = 3, p = 0.000 and $\chi^2 = 18.31$, df = 1, p = 0.000, respectively).

In Set 2, there was a significant relationship between gender and playing computer games ($\chi^2 = 8.46$, df = 1, p = 0.004). However, there was no significant relationship between gender and frequency of playing computer games (see Appendix E, Table E17). There were significant relationships between gender and playing computer games in years, and between gender and playing games with a shooting genre ($\chi^2 = 24.68$, df = 3, p = 0.000 and $\chi^2 = 18.06$, df = 1, p = 0.000, respectively).

According to the independent t-tests for Set 1, there was a significant difference between gender and playing computer games. The mean of playing computer games of female participants ($M = 1.27$, $SD = 0.45$) was significantly higher ($t = 2.24$, $df = 88$, two-tailed $p = 0.027$) than that of male participants ($M = 1.09$, $SD = 0.29$). There was a significant difference between gender and frequency of playing computer games. The mean of frequency of playing computer games of male participants ($M = 2.34$, $SD = 0.79$) was significantly higher ($t = -3.96$, $df = 72$, two-tailed $p = 0.000$) than that of female participants ($M = 1.58$, $SD = 0.87$). Male participants played computer games more than once in a week, whereas female participants played less than once in a week. There was a significant difference between gender and playing computer games in years. The mean years of playing computer games of male participants ($M = 3.10$, $SD = 0.83$) was significantly higher ($t = -6.64$, $df = 72$, two-tailed $p = 0.000$) than that of female participants ($M = 1.76$, $SD = 0.90$). Male participants played computer games longer than female participants. In addition, there was a significant difference between gender and playing shooting games. The mean of playing shooting games of female participants ($M = 1.88$, $SD = 0.33$) was significantly higher ($t = 4.87$, $df = 72$, two-tailed $p = 0.000$) than that of male participants ($M = 1.39$, $SD = 0.49$).

According to the independent t-tests for Set 2, there was a significant difference between gender and playing computer games. The mean of playing computer games of female participants ($M = 1.27$, $SD = 0.45$) was significantly higher ($t = 3.02$, $df = 88$, two-tailed $p = 0.003$) than that of male participants ($M = 1.04$, $SD = 0.21$).

There was no significant difference between gender and frequency of playing computer games (see Appendix E, Table E18). There was a significant difference between gender and playing computer games in years. The mean years of playing computer games of male participants (M = 3.16, SD = 0.88) was significantly higher (t = -4.55, df = 76, two-tailed p = 0.000) than that of female participants (M = 2.09, SD = 1.19). Male participants played computer games longer than female participants. In addition, there was a significant difference between gender and playing shooting games. The mean of playing shooting games of female participants (M = 1.82, SD = 0.39) was significantly higher (t = 4.79, df = 76, two-tailed p = 0.000) than that of male participants (M = 1.34, SD = 0.48).

5.2.2.4 Gender Differences during the Virtual Navigation

In order to understand the reasons behind the staircase preferences, 28 items were identified from the participants' responses from the open-ended questions (see Appendix C, Questions 3 and 7 for Set 1 and Set 2). These items were classified under 5 attributes as: 1. Distance, 2. Angular Position, 3. View Direction, 4. Personal Feeling and 5. Personal Preference. The first three attributes were formed with respect to the definition of a geometric attribute and the latter were based on the participants (see Table 7).

Table 7. Classification of the reasons for utilizing the staircases

1. DISTANCE
11. Close to the last visited room
12. Close to participant
13. Close to the exit

2. ANGULAR POSITION
21. In the center, close to everywhere
22. The idea of the first floor being perceived better
23. Not to turn, was on a straight line
24. This staircase had an orientation, whereas the steps of the other staircase was on the opposite side

3. VIEW DIRECTION
31. The first staircase that I saw from the entrance door
32. Infront of the room that I last visited, within the point of view
33. Infront of the exit/entrance when descending
34. On my right
35. On my left
36. According to the direction of the circulation path, starting from the left and finishing on the right
37. On the right side of the entrance
38. On the left side of the entrance

4. PERSONAL FEELING
41. The staircase in the middle was like the primary staircase
42. The staircase on the side wall was like a fire exit staircase
43. Being in the middle seemed more safer
44. Being on the side wall seemed more safer
45. Going up/down from this staircase was easier
46. Being in the corner made be uncomfortable
47. The staircase on the side wall seemed more private

5. PERSONAL PREFERENCE
51. Went up from one, went down from the other. Utilize one staircase for going up and the other for going down
52. Curious, wanted to experience it
53. Familiar
54. For the sake of a change
55. Saw it while navigating on the ground floor
56. Wanted to walk-spend more time

The 'distance' indicated the proximity between the participant, exit and the last visited room. The visibility of the environment, the perception of the first floor and the orientation (climbing direction) of the staircase with respect to the participant were defined under the heading ‘angular position’. In the ‘view direction’ attribute, 2 relationships were identified; the relationship between the participant and the staircase was clarified by the direction of the cue according to the participant’s right left or front and circulation path. The second relationship was between the entrance and the participant; the direction of the cue was described with respect to the entrance. In the ‘personal feeling’ attribute, the participants indicated their feelings towards the staircase as being safer, easier, comfortable and private, and the importance of the staircase. The ‘personal preference’ attribute indicated the participants’ personal reasons for choosing a specific staircase during navigation in the VE.

According to the results of Set 1, there were a similar number of participants in choosing Room 1 and Room 3 as their starting point of navigation on the ground floor. On the first floor, more than half of the participants started at Room 6 (Table 8).

Table 8. First visited room preferences on ground and first floors of Set 1 in the VE

	First Visited Room on Ground Floor			First Visited Room on First Floor		
Gender	Room 1 (123/132)	Room 2 (213/23)	Room 3 (312/321)	Room 4 (45/465)	Room 5 (5)	Room 6 (645/65)
Female	25	1	19	19	2	24
Male	18	6	21	20	1	24
Total	43	7	40	39	3	48

Thirty-eight participants utilized the staircase in the middle for ascending and descending (Table 9). The reason for choosing this staircase was due to the ‘angular position’ and ‘distance’ attributes; it was in the center and close to the last visited room.

Table 9. Staircase preferences for Set 1 in the VE

	Staircase Preferences			
Gender	A-A	A-B	B-A	B-B
Female	7	12	11	15
Male	4	10	8	23
Total	11	22	19	38

For Set 2, more than half of the participants preferred to start at Room 3 on the ground floor and Room 4 on the first floor. In both cases, the majority of the genders preferred these rooms (Table 10).

Table 10. First visited room preferences on ground and first floors of Set 2 in the VE

	First Visited Room on Ground Floor			First Visited Room on First Floor		
Gender	Room 1 (123/132)	Room 2 (213/231)	Room 3 (312/321)	Room 4 (45/465)	Room 5 (5)	Room 6 (645/65)
Female	10	16	19	22	5	18
Male	7	11	27	24	10	11
Total	17	27	46	46	15	29

More than half of the participants utilized the same staircase for ascending and descending; 30 participants utilized the staircase on the right of the entrance and 25 utilized the staircase on the left (see Table 11). The participants indicated that ‘distance’, which is being close to the last visited room on the ground floor and ‘personal preference’, which is familiarity with the same staircase, determined their staircase preference.

Table 11. Staircase preferences for Set 2 in the VE

	Staircase Preferences			
Gender	A-A	A-C	C-A	C-C
Female	7	13	5	20
Male	18	10	7	10
Total	25	23	12	30

Chi-square analysis indicated that there were no significant relationships between gender and the first visited rooms on the ground and first floors of Set 1 (see Appendix E, Tables E19 and E20, respectively). In addition, there were no significant relationships between gender and the first visited rooms on the ground and first floors of Set 2 (see Appendix E, Tables E19 and E20, respectively).

A further analysis was conducted in order to see if there was a significant relationship between gender and the direction of navigation, in other words, did the participants continue their room visits in a clockwise or in an anti-clockwise manner for the ground and first floors of Set 1 and Set 2? Participants who navigated in a clockwise manner began at any room and then visited the other rooms in a clockwise manner, for example participants could visit the rooms as: Room 1 – Room 2 – Room 3, Room 2 – Room 3 – Room 1, Room 3 – Room 1 – Room 2 for the ground floor, and Room 4 – Room 5 and Room 6 – Room 4 – Room 5 for the first floor. This was the reverse for the anti-clockwise navigation.

According to the chi-square analysis, there were no significant relationships between gender and the direction of the navigation for the ground and first floors of Set 1 (see Appendix E, Tables E21 and E22, respectively), and for the ground and first floors of Set 2 (see Appendix E, Tables E21 and E22, respectively).

There were no significant relationships between gender and staircase preferences for ascending in Set 1 and Set 2 (see Appendix E, Table E23). There was no significant relationship between gender and staircase preferences for descending in Set 1 (see Appendix E, Table E24). However, there was a significant relationship between gender and staircase preferences for descending in Set 2 ($\chi^2 = 7.76$, df = 1, $p = 0.005$). According to the independent t-test, the mean staircase preferences for descending of female participants (M = 2.47, SD = 0.89) was significantly higher ($t = 2.88$, df = 88, two-tailed $p = 0.005$) than that of male participants (M = 1.89, SD = 1.00).

In the virtual navigation total durations of Set 1 and Set 2, the mean score was 97.14 seconds (SD = 35.68) and the range was from 60 seconds to 231 seconds. The navigation durations were grouped into 4 categories as: 60-72sec, 73-85sec, 86-106sec and 107-231sec. These categories were formed by the 25th, 50th and 75th percentiles. Classifications as below and above the mean were not considered since there would be a pile of participants at one end.

Table 12. Distribution of virtual navigation total durations according to gender for both sets in the VE

Set	Gender	Virtual Navigation Total Durations 60sec-72sec	73sec-85sec	86sec-106sec	107sec-231sec
Set 1	Female	3	4	12	26
	Male	16	17	10	2
Set 2	Female	3	9	15	18
	Male	20	17	8	0

According to Table 12, in both sets, male participants completed the virtual navigation in a shorter period of time than female participants. Chi-square analysis indicated that there were significant relationships between gender and the virtual navigation total durations for both Set 1 and Set 2 ($\chi^2 = 37.70$, df = 3, p = 0.000 and $\chi^2 = 35.16$, df = 3, p = 0.000, respectively).

In Set 1, the mean virtual navigation total durations of female participants (M = 3.36, SD = 0.91) was significantly higher (t = 7.43, df = 88, two-tailed p = 0.000) than that of male participants (M = 1.96, SD = 0.88). Similarly, in Set 2, the mean virtual navigation total durations of female participants (M = 3.07, SD = 0.94) was significantly higher (t = 7.44, df =88, two-tailed p = 0.000) than that of male participants (M = 1.73, SD = 0.751). In both sets, female participants completed the virtual navigation in a longer period of time than male participants.

5.2.2.5 Summary of Gender Differences

Table 13 depicts a summary of the gender differences with respect to sense of direction, sense of presence, computer familiarity, computer experience and properties of the virtual navigation within each set.

Table 13. Gender differences within each set

		Set 1	Set 2	*Overall*
Gender	SOD	F > M	F = M	*F > M*
	SOP	F = M	F = M	*F = M*
	Comp. Fam.	F > M	F = M	*F > M*
	Play Comp. Game	F > M	F > M	*F > M*
	Comp. Game Usage	F < M	F = M	*F < M*
	Play Comp. in Years	F < M	F < M	*F < M*
	Play Shooting Games	F > M	F > M	*F > M*
	1st Room - Ground	F = M	F = M	
	1st Room - First	F = M	F = M	
	Direction - Ground	F = M	F = M	
	Direction - First	F = M	F = M	
	Staircase - Ascend	F = M	F = M	
	Staircase - Descend	F = M	F > M	
	Nav. Total Duration	F > M	F > M	

5.2.3 Related to Navigational Abilities during the Virtual Navigation

Navigational abilities with respect to sense of direction, sense of presence, computer familiarity, frequency of playing computer games and playing computer games in years were examined between the staircase preferences for ascending and descending in each set. In Set 1 and Set 2, there were no significant relationships between sense of direction and the staircase preferences for ascending and descending (see Appendix E, Tables E25 and E26, respectively). There were no significant relationships between sense of presence and the staircase preferences for ascending and descending for Set 1 and Set 2 (see Appendix E, Tables E27 and E28, respectively). In addition, there were no significant relationships between computer familiarity and the staircase preferences for ascending and descending for both sets (see Appendix E, Tables E29 and E30, respectively).

In Set 1, there was no significant relationship between frequency of playing computer games and the staircase preferences for ascending (see Appendix E, Table E31); however, there was a significant relationship between frequency of playing computer games and the staircase preferences for descending ($\chi^2 = 8.97$, df = 2, $p = 0.011$). In Set 2, there was no significant relationship between frequency of playing computer games and the staircase preferences for ascending and descending (see Appendix E, Tables E31 and E32, respectively). Likewise, there was no significant relationship between playing computer games in years and the staircase preferences for ascending and descending for both sets (see Appendix E, Tables E33 and E34, respectively).

The uncorrelated analysis of variance (ANOVA) test was conducted to find if the staircase preference for descending within the computer game usage had different means in Set 1. The effect of the computer game usage was significant overall ($F_{2,71} = 4.90$, $p = 0.010$). When a Bonferroni adjustment was made for the number of comparisons, there were two significant differences. The mean of "once in a week" ($M = 1.86$, $SD = 0.36$) was significantly higher ($t = -2.58$, $df = 42$, two-tailed $p = 0.013$) than that of "less than once in a week" ($M = 1.47$, $SD = 0.51$) and the mean of "more than once in a week" ($M = 1.77$, $SD = 0.43$) was significantly higher ($t = -2.47$, $df = 58$, two-tailed $p = 0.016$) than that of "less than once in a week" ($M = 1.47$, $SD = 0.51$). There was no significant difference between the means of "once in a week" and "more than once in a week" (see Appendix E, Table E35). Table 14 depicts the results of the navigational abilities during the virtual navigation.

Table 14. Navigational abilities during the virtual navigation

			Set 1	Set 2
Navigational Abilities	SOD	Staircase - Ascend	GSOD = PSOD	GSOD = PSOD
		Staircase - Descend	GSOD = PSOD	GSOD = PSOD
	SOP	Staircase - Ascend	GSOP = PSOP	GSOP = PSOP
		Staircase - Descend	GSOP = PSOP	GSOP = PSOP
	Comp. Fam.	Staircase - Ascend	GCF = PCF	GCF = PCF
		Staircase - Descend	GCF = PCF	GCF = PCF
	Comp. Usage	Staircase - Ascend	R = O = F	R = O = F
		Staircase - Descend	O > R, F >R	R = O = F
			* Rare, Once, Frequently	
	Play Comp. in Years	Staircase - Ascend	No Relationship	No Relationship
		Staircase - Descend	No Relationship	No Relationship

5.2.4 Related to the Cue Pairs with 90° and 180° Differences

In order to test whether a 90° difference (Set 1) or a 180° difference (Set 2) between the cue pairs were efficient in the VE with respect to the first visited rooms on the ground and first floors, staircase preferences and virtual navigation total durations. Independent sample t-tests and bivariate correlation tests were conducted.

5.2.4.1 According to the First Visited Room

The mean of the first visited room on the ground floor in Set 2 ($M = 2.32$, $SD = 0.78$) was significantly higher ($t = -2.72$, $df = 178$, two-tailed $p = 0.007$) than that of Set 1 ($M = 1.97$, $SD = 0.97$). With respect to the correlation test, there was a low positive significant relationship between Set 1 and Set 2 in the circulation path of the ground floor with respect to the first visited room ($r = 0.20$, $df = 178$, $p < 0.007$).

On the other hand, the mean of the first visited room on the first floor in Set 1 ($M = 2.10$, $SD = 0.98$) was significantly higher ($t = 2.06$, $df = 178$, two-tailed $p = 0.041$) than that of Set 2 ($M = 1.81$, $SD = 0.90$). With respect to the correlation test, there was a low negative significant relationship between Set 1 and Set 2 in the circulation path of the first floor with respect to the first visited room ($r = -0.15$, $df = 178$, $p < 0.041$).

5.2.4.2 According to the Staircase Preferences

According to the staircase preferences for ascending, the mean of the staircase preferences for ascending in Set 2 ($M = 1.93$, $SD = 1.00$) was significantly higher ($t = -2.55$, $df = 178$, two-tailed $p = 0.011$) than that of Set 1 ($M = 1.63$, $SD = 0.49$). With respect to the correlation test, there was a low positive significant relationship between Set 1 and Set 2 in the staircase preferences for ascending ($r = 0.19$, $df = 178$, $p < 0.011$). Likewise, the mean of the staircase preferences for descending in Set 2 ($M = 2.18$, $SD = 0.99$) was significantly higher ($t = -4.42$, $df = 178$, two-tailed $p = 0.000$) than that of Set 1 ($M = 1.67$, $SD = 0.47$). The correlation test indicated that there was a low positive significant relationship between Set 1 and Set 2 in the staircase preferences for descending ($r = 0.31$, $df = 178$, $p < 0.000$).

5.2.4.3 According to the Virtual Navigation Total Durations

The independent t-test indicated that there was no a significant difference between Set 1 and Set 2 with respect to the virtual navigation total durations (see Appendix E, Table E36).

5.2.4.4 Summary of the Cue Pairs

Table 15 depicts a summary of the cue pairs with respect to the first visited rooms on the ground and first floors, staircase preferences and virtual navigation total durations.

Table 15. Cue pairs with 90° and 180° differences

Cue Pairs	1st Room - Ground	Set 1 < Set 2	Low (+) Correlation
	1st Room - First	Set 1 > Set 2	Low (-) Correlation
	Staircase - Ascend	Set 1 < Set 2	Low (+) Correlation
	Staircase - Descend	Set 1 < Set 2	Low (+) Correlation
	Nav. Total Duration	Set 1 = Set 2	

5.3 Discussion

The previous studies in literature related to staircases mainly focused either on the environmental features that affect staircase use (Olander, 2009; Nicoll, 2007) or simulation systems that are based on evacuation of buildings through the use of staircases (Sun, 2009). The present study aims to understand how staircases can be utilized during virtual navigation and how they affect vertical navigation in a novel multi-level desktop VE.

As Riecke et al. (2002) demonstrated, purely visual navigation is sufficient for basic navigation tasks in a VE. With respect to the virtual navigation, it is hypothesized that there is a difference between ascending and descending staircase preferences of users in the VE. The ascending staircase preference for the VEs with a 90° difference and a 180° difference between the cue pairs are evaluated according to the first and last visited rooms on the ground floor (see Table 4). In the VE with a 90° difference between the cue pairs, there was no significant difference between the staircases A and B, even though it was stated that Staircase B was the main staircase by the participants. However, according to the first visited room in the VE with a 180° difference between the cue pairs, Staircase A was preferred more than Staircase C since the participants started their virtual navigation from Room 1 (the room on the left side in Figure 10a) and finished at Room 3 (the room on the right side in Figure 10a). This indicated that the participants utilized the staircase that they saw first while entering Room 1 in the VE; in other words, the 'view direction' attribute is influential in the staircase preference.

On the other hand, with respect to the last visited room of the VE with a 180° difference between the cue pairs, Staircase C is utilized more than Staircase A for descending. Even though the distance from the staircase to the entrance/exit is kept constant, the distance from the staircase to the rooms varies; this caused the participants to prefer the closest staircase to the last visited room (see Table 4). As a result 'distance' was a determining attribute for the staircase preference. One could have expected a similar difference in the VE with a 90° difference between the cue pairs since the staircases are positioned differently in the VE. However, the results showed that when the angle between the cue pairs is greater than 90°, participants' preference differ according to the first and last visited rooms. Another interesting finding is related to the participants' view directions; especially in the VE with a 180° difference between the cue pairs, the participants utilized the staircases that are situated on the left side of their view directions. The tendency of people to do things from left to right is related to the individual's culturally determined writing and reading habits (De Agostini et al., 2010; Maass et al., 2007; Maass et al., 2009). Maass et al. (2007) claimed that the directional bias in an individual's perception is based on the writing and reading habits, in other words, exploring an environment in a specific direction is related to the directionality of writing and reading. Individuals explore an environment with a left to right trajectory and process the spatial information easier when they follow a left to right directionality (Maass et al., 2009).

Since previous studies in gender (Barkley and Gabriel, 2007; Chai and Jacobs, 2009; Coluccia and Louse, 2004; Picucci et al., 2011; Sandstrom et al., 1998; Saucier et al., 2003; Tlauka et al., 2005) indicated that females tend to refer to landmarks more often than men; in other words, females use landmark information to find their way in new environments, whereas males tend to use both geometric and landmark information. In addition, it was found that females rely more on landmarks and have better object memory than men in remembering the location and identity of 2D objects (Barkley and Gabriel, 2007; James and Kimura, 1997; Levy et al., 2005; Voyer et al., 2007). It is hypothesized that there is a relationship between gender and staircase preferences in the VE and females prefer the staircase that they see first in the desktop VE during the virtual navigation. However, no relationship was determined between gender and staircase preferences for ascending and descending in the VE with a 90° difference between the cue pairs, and for ascending in the VE with a 180° difference between the cue pairs. In line with Iachini et al.'s study (2005), there was no gender difference in object recognition in a real 3D environment. The only relationship between gender and the descending staircase was found as the Staircase A in the VE with a 180° difference between the cue pairs (see Table 13), which was located on the right side of the last visited room on the first floor, was in favor of females (see Figure 10b). This could indicate that when two cues are in equal distance and are opposite to each other, females are more orientated than males to the cue on the right side. Alexander et al. (2002) showed that females have a better memory for object locations in the right visual field. Likewise, De Goede (2009) found that object-identity memory and object-location memory were better retrieved when located in the right visual field; however, they did not note a gender difference. The visibility of the staircases from the rooms could be a factor that could affect the participants' memory of the cues; however, further research has to be conducted to elaborate the tendency of females towards the right side and the visibility of the cues.

Sholl et al. (2000) indicated that people with a good sense of direction (GSOD) actively explore and focus on details in new environments and they remember new routes, whereas participants with a poor sense of direction (PSOD) worry about getting lost, feel more anxious and more likely to lose their way (Hund and Padgitt, 2010; Padgitt and Hund, 2012). With respect to Sholl et al.'s (2000) findings, in this study, it is hypothesized that there is a relationship between sense of direction and staircase preference of the participants. The participants with a GSOD would utilize different staircases in the two sets since they are able to explore and attend to different cues in the VE while the participants with a PSOD would prefer the same staircase for ascending and descending. However, the results indicated that there is no relationship between sense of direction and staircase preference in the VE and the participants with a PSOD do not prefer a specific staircase during the virtual navigation (see Table 14). This might be related to the clear visibility of the staircases and less complexity of the environment. Both staircases for ascending and descending were visible to the participants when they left the last room, so the participants with a PSOD did not have to worry about getting lost. If the environment consisted of more details and cues, there might have been a difference in staircase preference between the participants with GSOD and PSOD. In addition, there was no difference between the VEs with a 90° difference and a 180° difference between the cue pairs with respect to sense of presence since the two VEs were the same except for the locations of the staircases; the presence levels were indifferent.

Even though various studies showed that as the experience with computer increases there is a better performance in visual search (Dye et al., 2009b) and visual memory (Ferguson et al., 2008), an increase in visual attention (Castel et al., 2005; Green and Bavelier, 2003; 2006; Spence et al., 2009), and leads to lower levels of computer anxiety (Bonzionelos, 2004; Gürcan-Namlu and Ceyhan, 2003; Tekinarslan, 2008), the present study revealed no relationships between the staircase preferences and computer familiarity, as well as between the staircase preferences and computer experience (see Table 14). It is hypothesized that the participants with a good computer familiarity (GCF) and with a high computer experience prefer different staircases for ascending and descending, whereas the participants with a poor computer familiarity (PCF) and low computer experience prefer the same staircase for ascending and descending. The reason for this indifference might be due to the similar computer experiences of the participants. The participants are familiar with the computer since they used it more than once a week. Also, they had the same educational background and they are familiar with computer-based environments due to the compulsory computer-based courses that they took during the second and third years of their education.

Since the locations of the staircase pairs were different in the two VEs, there was a significant difference between the cue pairs of a 90° difference and a 180° difference with respect to the first visited rooms on the ground and first floors of the VE (see Table 15). The cue pair of a 90° difference was in favor with respect to the first visited room on the first floor and the cue pair of a 180° difference was in favor with respect to the first visited room on the ground floor. In the VE with a 180° difference between the cue pairs, all of the rooms were visible when the participants entered the VE and there was not a staircase in the middle that interfered with the view of the participants. In the VE with a 90° difference between the cue pairs, some participants indicated that they did not notice Room 2, which was directly across the entrance due to the staircase in the middle (see Figure 9a). There was a significant difference between the cue pairs of a 90° difference and a 180° difference with respect to the staircase preferences for ascending and descending in which the cue pair of a 180° difference was in favor (see Table 15). Both staircases were located along the side walls that enabled the participants to easily see them from the rooms (see Figure 10). There was no difference between the cue pairs of a 90° difference and a 180° difference with respect to the virtual navigation total durations. Although in the cue pair of a 90° difference, there was a staircase in the middle (Staircase B) that would interfere with the virtual navigation, the results indicated no difference.

CHAPTER 6

CONCLUSION

A staircase is an important local architectural cue that enables movement between the different levels of a building. As Hölscher et al. (2006) stated the position of the staircase has to be designed accordingly with the individual's activity within the building. However, individuals can loose their orientation during vertical travel. In order to understand the role of staircases in a novel multi-level desktop VE, a model is formulated that integrates gender, navigational abilities and the geometric attributes of the staircase during navigation.

In the present research, two VEs were provided with the angle between the cue pairs (staircases) from the observation point either as 90° or 180°. According to the findings of the research, a 90° difference between the cue pairs did not have an effect on the staircase preferences; however, in a 180° difference, staircase preferences differed according to the order of the visited rooms during virtual navigation. There was no gender difference between the staircase preferences with a 90° and 180° difference, except for Staircase A in the cue pair with a 180° difference that was utilized more for descending by females. Further analysis needs to be conducted in order to understand the tendency of females in preference of cues on their right side. Individual's navigation abilities with respect to the sense of direction, computer familiarity and computer experience did not have an effect on the staircases preferences within the two VEs. The cue pair with an angle difference of 180° was preferred more during ascending and descending.

Based on this study, the following guideline for interior architects can be suggested:

1. Locate staircases so that they are visible from where people are located in the building.
2. Locate staircases according to the individual's circulation path. For easy access to the lower or upper floors, locate staircases in close proximity to the last visited area. For exploration of the building, locate staircases in close proximity to the entrance.
3. To emphasize a certain staircase, locate that staircase within the central area of the building and make it visible either from the entrance or from the last visited area in the building.
4. In novel buildings, in which the individual has no prior knowledge about the building, individuals prefer the same staircase that they utilized for ascending and descending. Make the staircase accessible and visible; enable direct visual communication.

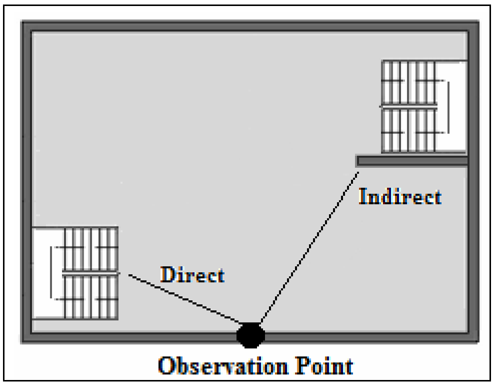

Figure 15. Direct and indirect visual communication

5. Orient the first steps of the staircases so that the individuals require less turns in order to enter the staircase from the entrance or from the last visited areas in the building.

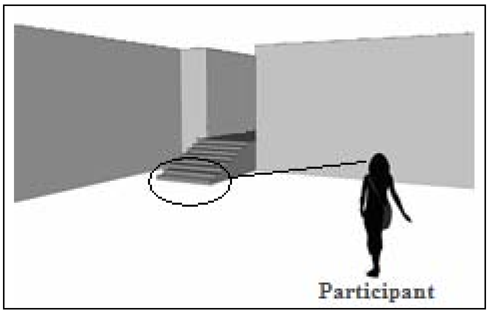

Figure 16. Visibility of the first steps of the staircase

6. Depending on the culture, an individual's exploration of an environment starts from the left and finishes on the right. Locate cues according to the individual's circulation path. To emphasize a certain cue, locate it at the beginning or at the end.
7. Locate cues related to females in the right visual field of the building in order for them to remember for future use.
8. To provide different utilizations of staircase pairs in buildings with more than one staircase, locate the staircase pairs further about from each other with an angle difference of more than 90°.

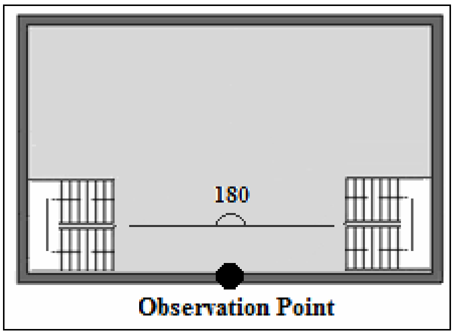

Figure 17. 180° difference between the staircase pairs

9. To provide equal utilizations of staircase pairs in buildings with more than one staircase, locate the staircase pairs at a 90° difference from the observation point.

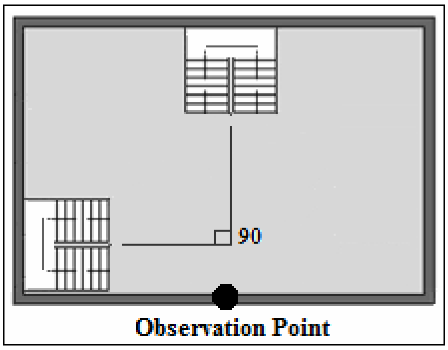

Figure 18. 90° difference between the staircase pairs

Various strengths related to the study are identified:

- With the aid of a VE, the geometric attributes of the staircases are designed with varying configurations and the most efficient location of the staircases is identified before the construction phase of the design process.
- The characteristics of the participants are identified and according to their characteristics, their movements within the VE and staircase preferences for ascending and descending are recorded and assessed separately.
- Designers are able to obtain an immersed view of the proposed building, assess and improve their designs, and understand the architectural

requirements that can ease spatial orientation or cause disorientation for people with different characteristics in order to avoid costly design mistakes.

- This study provides an understanding on the position of the staircases with respect to the entrance and the rooms, and the individual's activity within the building. This can shed light on the design and position of staircases within hospitals, shopping malls, universities and large complexes.

On the other hand, various limitations can be stated:

- The study was conducted only with 'U-type' staircases.
- The building in the VE was simple in which there were two floors with three rooms on each floor and the two staircases were visible.
- The study was conducted with students having the same design educational background.
- The age group of the interior architecture students was restricted.
- The study concentrated only on the staircases as an element of local architectural cues.

For further research, the form of the staircases can be varied by utilizing a 'line-type' or a 'L-type' staircase. The visibility of the staircases can be varied by having circulation paths i.e. corridors or hallways that lead to the staircases, and placing staircases at different angles other than 90° and 180°. The design of the VE can be elaborated by having more floors for vertical circulation, more rooms to visit and an asymmetrical spatial organization since the present VE was symmetrical. The VE could constitute a function, like a hospital, shopping mall or university. The effects of different local architectural cues for vertical navigation can be investigated. A comparison between left-handed and right-handed participants can be done in order to understand the effects of handedness on the staircases during vertical navigation.

The staircase preferences of individuals from different age groups and with different educational backgrounds can be investigated.

BIBLIOGRAPHY

Alexander, G. M., M. G. Packard and B. S. Peterson. 2002. "Sex and Spatial Position Effects on Object Location Memory Following Intentional Learning of Object Identities," *Neuropsychologia* 40(8): 1516-1522.

Allen, G. L. 1999. "Spatial Abilities, Cognitive Maps, and Wayfinding: Bases for Individual Differences in Spatial Cognitive and Behavior." In R. G. Golledge, ed., *Wayfinding Behavior: Cognitive Mapping and Other Spatial Processes*. Baltimore: The John Hopkins University Press, 46-80.

Alsina-Jurnet, I., C. C. Beciu and J. Gutiérrez-Maldonado. 2005. "Individual Differences in the Sense of Presence." Proceedings of "PRESENCE 2005: The 8th Annual International Workshop on Presence," held in London, UK. Retrieved February 22, 2012, from http://www.temple.edu/ispr/prev_conferences/proceedings/2005/Jurnet,%20Beciu,%20Maldonado.pdf.

Alsina-Jurnet, I. and J. Gutiérrez-Maldonado. 2010. "Influence of Personality and Individual Abilities on the Sense of Presence Experienced in Anxiety Triggering Virtual Environments," *International Journal of Human-Computer Studies* 68(10): 788-801.

Arns, L. 2002. "A New Taxonomy for Locomotion in Virtual Environments." Unpublished doctoral dissertation. Iowa: Iowa State University.

Arthur, P. and R. Passini. 1992. *Wayfinding: People, Signs and Architecture*. New York: McGraw-Hill Company.

Barkley, C. L. and K. I. Gabriel. 2007. "Sex Differences in Cue Perception in a Visual Scene: Investigation of Cue Type," *Behavioral Neuroscience* 121(2): 291-300.

Barnett, M. A. and et al. 1997. "Late Adolescents' Experiences With and Attitudes Toward Videogames," *Journal of Applied Social Psychology* 27(15): 1316-1334.

Beckers, J. J., R. M. J. P. Rikers and H. G. Schmidt. 2006. "The Influence of Computer Anxiety on Experienced Computer Users While Performing Complex Computer Tasks," *Computers in Human Behavior* 22: 456-466.

Beckers, J. J. and H. G. Schmidt. 2001. "The Structure of Computer Anxiety: A Six-Factor Model," *Computers in Human Behavior* 17(1): 35-49.

-----. 2003. "Computer Experience and Computer Anxiety," *Computers in Human Behavior* 19(3): 785-797.

Belingard, L. and P. Peruch. 2000. "Mental Representation and the Spatial Structure of Virtual Environments," *Environment and Behavior* 32(3): 427-442.

Bell, S. and D. Saucier. 2004. "Relationship among Environmental Pointing Accuracy, Mental Rotation, Sex, and Hormones," *Environment and Behavior* 36(2): 251-265.

Boot, W. R. and et al. 2008. "The Effects of Video Game Playing on Attention, Memory, and Executive Control," *Acta Psychologica* 129(3): 387-398.

Bowman, D. A. and et al. 1999. "Maintaining Spatial Orientation during Travel in an Immersive Virtual Environment," *Presence* 8(6): 618-631.

Bowman, D., D. Koller and L. Hodges. 1997. "Travel in Immersive Virtual Environments: An Evaluation of Viewpoint Motion Control Techniques." Proceedings of the "Virtual Reality Annual International Symposium," held in Albuquerque, NM, USA, March 1-5, 45-52.

----- . 1998. "A Methodology for the Evaluation of Travel Techniques for Immersive Virtual Environments," *Virtual Reality: Research, Development, and Applications* 3: 120-131.

Bozionelos, N. 2001. "Computer Anxiety: Relationship with Computer Experience and Prevalence," *Computers in Human Behavior* 17: 213-224.

-----. 2004. "Socio-Economic Background and Computer Use: The Role of Computer Anxiety and Computer Experience in their Relationship," *International Journal of Human-Computer Studies* 61(5): 725-746.

Bungum, T., M. Meacham and N. Truax. 2007. "The Effects of Signage and the Physical Environment on Stair Usage," *Journal of Physical Activity and Health* 4(3): 237-244.

Burdea, G. C. and P. Coiffet. (2003). *Virtual Reality Technology*. (2nd ed.) New Jersey: Wiley.

Burigat, S. and L. Chittaro. 2007. "Navigation in 3D Virtual Environments: Effects of User Experience and Location-Pointing Navigation Aids," *International Journal of Human-Computer Studies* 65(11): 945-958.

Castel, A. D., J. Pratt and E. Drummond. 2005. "The Effects of Action Video Game Experience on the Time Course of Inhibition of Return and the Efficiency of Visual Search," *Acta Psychologica* 119(2): 217-230.

Castelli, L., L. L. Corazzini and G. C. Geminiani. 2008. "Spatial Navigation in Large-Scale Virtual Environments: Gender Differences in Survey Tasks," *Computers in Human Behavior* 24: 1643-1667.

Chai, X. J. and L. F. Jacobs. 2009. "Sex Differences in Cue Perception in a Visual Scene: Investigation of Cue Type," *Behavioral Neuroscience* 123(2): 276-283.

Chen, C.-H., W.-C. Chang and W.-T. Chang. 2009. "Gender Differences in Relation to Wayfinding Strategies, Navigational Support Design, and Wayfinding Task Difficulty," *Journal of Environmental Psychology* 29: 220-226.

Chen, J. L. and K. M. Stanney. 1999. "A Theoretical Model of Wayfinding in Virtual Environments: Proposed Strategies for Navigational Aiding," *Presence* 8(6): 671-685.

Cherney, I. D. 2008. "Mom, Let Me Play More Computer Games: They Improve My Mental Rotation Skills," *Sex Roles* 59(11-12): 776-786.

Cherney, I. D., C. M. Brabec and D. V. Runco. 2008. "Mapping Out Spatial Ability: Sex Differences in Way-Finding Ability," *Perceptual and Motor Skills* 107(3): 747-760.

Cherney, I. D. and K. L. London. 2006. "Gender-Linked Differences in the Toys, Television Shows, Computer Games, and Outdoor Activities of 5- to 13-Year-Old Children," *Sex Roles* 54: 717-726.

Coluccia, E., G. Iosue and M. A. Brandimonte A. 2007. "The Relationship Between Map Drawing and Spatial Orientation Abilities: A Study of Gender Differences," *Journal of Environmental Psychology* 27: 135-144.

Coluccia, E. and G. Louse. 2004. "Gender Differences in Spatial Orientation: A Review," *Journal of Environmental Psychology* 24: 329-340.

Conroy-Dalton, R. A. 2003. "The Secret is to Follow Your Nose: Route Path Selection and Angularity," *Environment and Behavior* 35: 107-131.

Cornell, E. H., A. Sorenson and T. Mio. 2003. "Human Sense of Direction and Wayfinding," *Annals of the Association of American Geographers* 93(2): 399-425.

Cutmore, T. R. H. and et al. 2000. "Cognitive and Gender Factors Influencing Navigation in a Virtual Environment," *International Journal of Human-Computer Studies* 53: 223-249.

Çubukcu, E. and J. L. Nasar. 2005. "Relation of Physical Form to Spatial Knowledge in Large-Scale Virtual Environments," *Environment and Behavior* 37: 397-417.

Dabbs, J. M. and et al. 1998. "Spatial Ability, Navigation Strategy, and Geographic Knowledge among Men and Women," *Evolution and Human Behavior* 19: 89-98.

Darken, R. P. and J. L. Sibert. 1996. "Wayfinding Strategies and Behaviors in Large Virtual Worlds." Proceedings of "CHI 96," held in Vancouver, British Columbia, Canada, April 13-18, 142-149.

De Agostini, M. and et al. 2010. "Visual Aesthetic Preference: Effects of Handedness, Sex, and Age-Related Reading/Writing Directional Scanning Experience," *Writing Systems Research* 2(2): 77-85.

De Goede, M. 2009. "Gender Differences in Spatial Cognition." Unpublished doctoral dissertation. Utrecht: Utrecht University. Retrieved June 26, 2012, from http://igitur-archive.library.uu.nl/dissertations/2009-0204-200942/de-goede.pdf.

De Goede, M. and A. Postma. 2008. "Gender Differences in Memory for Objects and Their Locations: A Study on Automatic versus Controlled Encoding and Retrieval Contexts," *Brain and Cognition* 66(3): 232-242.

Devlin, A. S. and J. Bernstein. 1995. "Interactive Wayfinding: Use of Cues by Men and Women," *Journal of Environmental Psychology* 15: 23-38.

Dinh, H. Q. and et al. 1999. "Evaluating the Importance of Multi-Sensory Input on Memory and the Sense of Presence in Virtual Environments." Proceedings of the "IEEE Virtual Reality 1999," held in Houston, TX, USA, March 13-17, 222-228.

Dye, M. W., C. S. Green and D. Bavelier. 2009a. "Increasing Speed of Processing with Action Video Games," *Current Directions in Psychological Science* 18: 321-326.

-----. 2009b. "The Development of Attention Skills in Action Video Game Players. *Neuropsychologia* 47: 1780-1789.

Feng, J., I. Spence and J. Pratt. 2007. "Playing an Action Video Game Reduces Gender Differences in Spatial Cognition," *Psychological Science* 18(10): 850-855.

Ferguson, C. J., A. M. Cruz and S. M. Rueda. 2008. "Gender, Video Game Playing Habits and Visual Memory Tasks," *Sex Roles* 58: 279-286.

Freksa, C., G. Vrachliotis and S. Bertel (eds.) 2004. "Mental Conceptions of Emergent Spaces in Architectural Design." Workshop No. 8 Proceedings "First International Conference on Design, Computation and Cognition," held in MIT, Cambridge.

Garland, K. J. and J. M. Noyes. 2004. “Computer Experience: A Poor Predictor of Computer Attitudes,” *Computers in Human Behavior* 20(6): 823-840.

Glenberg, A. M. 1997. “What Memory is For,” *Behavioral and Brain Sciences* 20(1): 1-55.

Green, C. S. and D. Bavelier. 2003. “Action Video Game Modifies Visual Selective Attention,” *Nature* 423: 534-537.

-----. 2006. “Effect of Action Video Games on the Spatial Distribution of Visuospatial Attention,” *Journal of Environmental Psychology: Human Perception and Performance* 32: 1465-1478.

----- . 2007. “Action Video-Game Experience Alters the Spatial Resolution of v Vision,” *Psychological Science* 18(1): 88-94.

Gürcan-Namlu, A. and E. Ceyhan. 2003. “Computer Anxiety: Multidimensional Analysis on Teacher Candidates,” *Educational Sciences: Theory & Practice* 3(2): 401-432.

Hartley, T. and et al. 2003. “The Well-Worn Route and the Path Less Traveled: Distinct Neural Bases of Route Following and Wayfinding in Humans,” *Neuron* 37: 877-888.

Hegarty, M. and et al. 2006. “Spatial Abilities at Different Scales: Individual Differences in Aptitude-Test Performance and Spatial-Layout Learning,” *Intelligence* 34: 151-176.

Hegarty, M. and et al. 2002. “Development of a Self-Report Measure of Environmental Spatial Ability,” *Intelligence* 30: 425-447.

Hendaoui, A., M. Limayem and C. W. Thompson. 2008. “3D Social Virtual Worlds: Research Issues and Challenges,” *IEEE Internet Computing* 12(1): 88-92.

Henson, D. B. 1993. *Visual Fields.* New York: Oxford University Press.

Heth, C. D., E. H. Cornell and T. L. Flood. 2002. “Self-Ratings of Sense of Direction and Route Reversal Performance,” *Applied Cognitive Psychology* 16: 309-324.

Hochmair, H. and A. U. Frank. 2002. “Influence of Estimation Errors on Wayfinding Decisions in Unknown Street Networks – Analyzing the Least-Angle strategy,” *Spatial Cognition and Computation* 2: 283-313.

Hou, J. and et al. 2012. “Effects of Screen Size, Viewing Angle, and Players’ Immersion Tendencies on Game Experience,” *Computers in Human Behavior* 28: 617-623.

Hölscher, C. and et al. 2005. “Finding the Way Inside: Linking Architectural Design Analysis and Cognitive Processes,” In C. Freksa and et al., eds., *Spatial Cognition IV – Reasoning, Action, Interaction*. Berlin: Springer-Verlag: 1-23.

Hölscher, C. and et al. 2006. “Up the Down Staircase: Wayfinding Strategies in Multi-Level Buildings,” *Journal of Environmental Psychology* 26: 284-299.

Hund, A. M., K. H. Haney and B. D. Seanor. 2008. “The Role Recipient Perspective in Giving and Following Wayfinding Directions,” *Applied Cognitive Psychology* 22: 896-916.

Hund, A. M. and J. L. Minarik. 2006. “Getting From Here to There: Spatial Anxiety, Wayfinding Strategies, Direction Type, Wayfinding Efficiency,” *Spatial Cognition and Computation* 6: 179-201.

Hund, A. M. and S. N. Nazarczuk. 2009. “The Effects of Sense of Direction and Training Experience on Wayfinding Efficiency,” *Journal of Environmental Psychology* 29: 151-159.

Hund, A. M. and A. J. Padgitt. 2010. “Direction Giving and Following in the Service of Wayfinding in a Complex Indoor Environment,” *Journal of Environmental Psychology* 30: 553-564.

Iachini, T., F. Ruotolo and G. Ruggiero. 2009. “The Effects of Familiarity and Gender on Spatial Representation,” *Journal of Environmental Psychology* 29: 227-234.

Iachini, T. and et al. 2005. “Gender Differences in Object Location Memory in a Real Three-Dimensional Environment,” *Brain and Cognition* 59: 52-59.

Igroup (2008). Retrieved May 9, 2012, from http://www.igroup.org/pq/ipq/index.php.

Imagery Lab. (n.d.). “Allocentric vs. Egocentric Spatial Processing.” Retrieved June 26, 2012, from http://www.nmr.mgh.harvard.edu/mkozhevnlab/?page_id=308.

James, T. W. and D. Kimura. 1997. “Sex Differences in Remembering the Location of Objects in an Array: Location-Shifts versus Location-Exchanges,” *Evolution and Human Behavior* 18: 155-163.

Jansen, S. E. M. 2012. “Obstacle Avoidance Behaviour during Locomotion: Strategy Changes as a Result of Visual Field Limitations,” Unpublished doctoral dissertation. Utrecht: Utrecht University. Retrieved July 15, 2012, from http://igitur-archive.library.uu.nl/dissertations/2012-0110-200359/Jansen.pdf.

Jeong, D. H. and et al. 2004. “Force-Based Velocity Control Technique in Immersive V.E.” Proceedings of “Graphite 2004,” held in Singapore, June 15-18, 237-241.

Jeong, D. H. and et al. 2009. “User Experimentation: An Evaluation of Velocity Control Techniques in Immersive Virtual Environments,” *Virtual Reality* 13: 41-50.

Jul, S. and G. W. Furnas. 1997. “Navigation in Electronic Worlds: A CHI’97 Workshop,” *ACM SIGCHI Bulletin* 29(4): 44-49.

Kato, Y. and Y. Takeuchi. 2003. “Individual Differences in Wayfinding Strategies,” *Journal of Environmental Psychology* 23: 171-188.

Kelly, J. W. and et al. 2008. “The Shape of Human Navigation: How Environmental Geometry is Used in Maintenance of Spatial Orientation,” *Cognition* 109: 281-286.

Kirschen, P. M. and et al. 2000. “Optic Flow Helps Humans Learn to Navigate through Synthetic Environments,” *Perception* 29: 801-818.

Kozlowski, L. T. and K. J. Bryant. 1977. “Sense of Direction Spatial Orientation, and Cognitive Maps,” *Journal of Experimental Psychology: Human Perception and Performance* 3: 590-598.

Lachlan, K. and M. Krcmar. 2008. "Experiencing Telepresence in Video Games: The Role of Telepresence Tendencies, Game Experience, Gender, and Time Spent in Play." Paper presented at the 94th Annual Meeting of "National Communication Association," 1-23. Retrieved February 20, 2012, from http://www.allacademic.com/meta/p256288_index.html.

Lapointe, J.-F. and P. Savard. 2007. "Comparison of Viewpoint Orientation Techniques for Desktop Virtual Walkthroughs." Proceedings of the "IEEE International Workshop on Haptic Audio Visual Environments and their Application," held in Ottawa, Ontario, Canada, October 12-14, 33-37.

Lapointe, J.-F., P. Savard and N. G. Vinson. 2011. "A Comparative Study of Four Input Devices for Desktop Virtual Walkthroughs," *Computers in Human Behavior* 27: 2186-2191.

Lapointe, J.-F. and N. G. Vinson. 2002. "Effects of Joystick Mapping and Field-of-View on Human Performance in Virtual Walkthroughs." Proceedings of the "IEEE International Symposium on 3D Data Processing Visualization and Transmission," held in Padova, Italy, June 18-21, 490-493.

Lavenex, P. B. and P. Lavenex. 2010. "Spatial Relational Learning and Memory Abilities do not differ between Men and Women in a Real-World, Open-Field Environment," *Behavioural Brain Research* 207: 125-137.

Lawson, B. 2001. *Language of Space.* Oxford: Architectural Press.

Lawton, C. A., S. I. Charleston and A. S. Zieles. 1996. "Individual- and Gender-Related Differences in Indoor Wayfinding," *Environment and Behavior* 28: 204-219.

Lawton, C. A. and J. Kallia. 2002. "Gender Differences in Wayfinding Strategies and Anxiety about Wayfinding: A Cross-Cultural Comparison," *Sex Roles* 47: (9/10), 389-401.

Lawton, C. A. and K. A. Morrin. 1999. "Gender Differences in Pointing Accuracy in Computer-Simulated 3D Mazes," *Sex Roles* 40: 73-92.

Lawton, M. P., B. Liebowitz and H. Charon. 1970. "Physical Structure and the Behavior of Senile Patients Following Ward Remodeling," *Aging and Human Development* 1: 231-239.

Le Corbusier. 1962. *An die Studenten, Die Charta d'Athenes*. Hamburg: Reinbek.

Lee, S. and G. J. Kim. 2008. "Effects of Visual Cues and Sustained Attention on Spatial Presence in Virtual Environments Based on Spatial and Object Distinction," *Interacting with Computers* 20: 491-502.

Lessels, S. and R. A. Ruddle. 2005. "Movement Around Real and Virtual Cluttered Environments," *Presence* 14: 580-596.

Lessiter, J. and et al. 2001. "A Cross-Media Presence Questionnaire: The ITC Sense of Presence Inventory," *Presence: Teleoperators and Virtual Environment* 10(3): 282-297.

Levy, L. J., R. S. Astur and K. M. Frick. 2005. "Men and Women Differ in Object Memory But Not Performance of a Virtual Radial Maze," *Behavioral Neuroscience* 119(4): 853-862.

Lin, C.-T. and et al. 2012. "Gender Differences in Wayfinding in Virtual Environments with Global and Local Landmarks," *Journal of Environmental Psychology* 32: 89-96.

Lombard, M. and T. Ditton. 1997. "At the Heart of It All: The Concept of Presence," *Journal of Computer-Mediated Communication*, 3(2). Retrieved February 15, 2012, from http://jcmc.indiana.edu/vol3/issue2/lombard.html.

Lombard, M. and et al. 2000. "Presence and Television: The Role of Screen Size," *Human Communication Research* 26: 75-98. Retrieved February 15, 2012, from http://jcmc.indiana.edu/vol3/issue2/lombard.html.

Ma, R. and D. B. Kaber. 2006. "Presence, Workload and Performance Effects of Synthetic Environment Design Factors," *International Journal of Human-Computer Studies* 64: 541-552.

Maass, A., D. Pagani and E. Berta. 2007. "How Beautiful is the Goal and How Violent is the Fistfight? Spatial Bias in the Interpretation of Human Behavior," *Social Cognition* 25(6): 833-852.

Maass, A. and et al. 2009. "Groups in Space: Stereotypes and the Spatial Agency Bias," *Journal of Experimental Social Psychology* 45(3): 496-504.

Mabini, A. T. 2009. “Improved Usability of Locomotion Devices Using Human-Gentric Taxonomy.” Unpublished doctoral dissertation, California: Naval Postgraduate School. Retrieved June 28, 2012, from http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA496741.

Martens, J. and P. D. Antonenko. 2012. “Narrowing Gender-Based Performance Gaps in Virtual Environment Navigation,” *Computers in Human Behavior* 28: 809-819.

Moffat, S. D., E. Hampson and M. Hatzipantelis. 1998. “Navigation in a “Virtual” Maze: Sex Differences and Correlation with Psychometric Measures of Spatial Ability in Humans,” *Evolution and Human Behavior* 19: 78-87.

Moffat, S. D., A. B. Zonderman and S. M. Resnick. 2001. “Age Differences in Spatial Memory in a Virtual Environment,” *Neurobiology of Aging* 22: 787-796.

Montello, D. R. and S. Freundschuh. (2005). Cognition of Geographic Information. In R. B. McMaster and E. L. Usery, eds., *A Research Agenda for Geographic Information Science*. Boca Raton, FL: CRC Press, 61-91.

Mou, W. and et al. 2004. “Allocentric and Egocentric Updating of Spatial Memories,” *Journal of Experimental Psychology: Learning, Memory, and Cognition* 30: 142-157.

Nicoll, G. 2006. “Taking the Stairs: Environmental Features That Predict Stair Use in 3 to 4 Story aAcademic Workplace Buildings.” Unpublished doctoral dissertation. Georgia: Georgia Institute of Technology. Retrieved May 9, 2012, from http://herg.gatech.edu/Files/nicoll_taking_the_stairs.pdf.

Nicoll, G. 2007. “Spatial Measures Associated with Stair Use,” *American Journal of Health Promotion* 21(4): 346-352.

Olander, E. K. 2009. “The Effectiveness of Contextual Cues in Encouraging Stair Use.” Unpublished doctoral dissertation. Birmingham: University of Birmingham. Retrieved June 2, 2012, from http://etheses.bham.ac.uk/1014/1/Olander10PhD.pdf.

O’Laughlin, E. M. and B. S. Brubaker. 1998. “Use of Landmarks in Cognitive Mapping: Gender Differences in Self Report versus Performance,” *Personality and Individual Differences* 24: 595-601.

Padgitt, A. J. and A. M. Hund. 2012. "How Good Are These Directions? Determining Direction Quality and Wayfinding Efficiency," *Journal of Environmental Psychology* 32: 164-172.

Passini, A. 1984. *Wayfinding in Architecure*. New York: Van Nostrand Reinhold.

----- .1996. "Wayfinding Design: Logic, Spplication and Some Thoughts on Universality," *Design Studies* 17: 319-331.

Picucci, L., A. O. Caffo and A. Bosco. 2011. "Besides Navigation Accuracy: Gender Differences in Strategy Selection and Level of Spatial Confidence," *Journal of Experimental Psychology* 31: 430-438.

Prestopnik, J. L. and B. Roskos-Ewoldsen. 2000. "The Relations among Wayfinding Strategy Use, Sense of Direction, Sex, Familiarity, and Wayfinding Ability," *Journal of Environmental Psychology* 20: 177-191.

Quaiser-Pohl, C., C. Geiser and W. Lehmann. 2006. "The Relationship Between Computer-Game Preference, Gender, and Mental-Rotation Ability," *Personality and Individual Differences* 40: 609-619.

Rapoport, A. 1982. *The Meaning of the Built Environment: A Nonverbal Communication Approach*. London: SAGE Publications.

Regenbrecht, H. and T. Schubert. 2002. "Real and Illusory Interactions Enhance Presence in Virtual Environments," *Presence: Teleoperators and Virtual Environment* 11(4): 425-434.

Richardson, A. E., M. E. Powers and L. G. Bousquet. 2011. "Video Game Experience Predicts Virtual, But Not Real Navigation Performance," *Computers in Human Behavior* 27: 552-560.

Riecke, B. E. 2003. "How Far Can We Get With Just Visual Information? Path Integration and Spatial Updating Studies in Virtual Reality." Unpublished doctoral dissertation. Tübingen: Eberhard-Karls-Üniversitat. Retrieved November, 29 2008, from http://tobias-lib.uni-tuebingen.de/volltexte/2003/999/pdf/thesis_final.pdf.

Riecke, B. E., H. A. H. C. van Veen and H. H. Bülthoff. 2002. "Visual Homing is Possible Without Landmarks: A Path Integration Study in Virtual Reality," *Presence: Teleoperators and Virtual Environments* 11: 443-473.

Rump, B. and T. P. McNamara. 2007. "Updating in Models of Spatial Memory." In T. Barkowsky and et al., eds., *Spatial Cognition V*. Berlin Heidelberg: Springer-Verlag, 249-269.

Sacau, A., J. Laarni and T. Hartmann. 2008. "Influence of Individual Factors on Presence," *Computers in Human Behavior* 24: 2255-2273.

Sadeghian, P. and et al. 2006. "The Frequent Wayfinding-Sequence (FWS) Methodology: Finding Preferred Routes in Complex Virtual Environments," *International Journal of Human-Computer Studies* 64: 356-374.

Sadowski, W. and K. M. Stanney. 2002. "Presence in the Virtual Environments," In K. M. Stanney, ed. *Handbook of Virtual Environments – Design, Implementation, and Applications.* Mahwah, New Jersey: Lawrence Erlbaum Associates, 791-806.

Sancaktar, I. and H. Demirkan. 2008. "Spatial Updating of Objects after Rotational and Translational Body Movements in Virtual Environments" *Computers in Human Behavior* 24: 2682-2696.

Sandstrom, N. J., J. Kaufman and S. A. Huettel. 1998. "Males and Females Use Different Distal Cues in a Virtual Environment Navigation Task," *Cognitive Brain Research* 6: 351-360.

Santos, B. S. and et al. 2009. "Head-Mounted Display versus Desktop for 3D Navigation in Virtual Reality: A User Study," *Multimedia Tools and Application* 41: 161-181.

Särkelä, H. and et al. 2009. "The Movement Patterns and the Experiential Components of Virtual Environments," *International Journal of Human-Computer Studies* 67: 787-799.

Sas, C. and G. M. P. O'Hare. 2003. "Presence Equation: An Investigation into Cognitive Factors Underlying Presence," *Presence: Teleoperators and Virtual Environments* 12(5): 523-537.

Saucier, D., M. Bowman and L. Elias. 2003. “Sex Differences in the Effect of Articulatory or Spatial Dual-Task Interference During Navigation,” *Brain and Cognition* 53: 346-350.

Schubert, T. W., F. Friedmann and H. T. Regenbrecht. 1999. “Embodied Presence in Virtual Environments,” In R. Paton and I. Neilson, eds., *Visual Representations and Interpretations*. London: Springer-Verlag, 268-278.

Schubert, T. W., F. Friedmann and H. T. Regenbrecht. 2001. “The Experience of Presence: Factor Analytic Insight,” *Presence: Teleoperators and Virtual Environment* 10(3): 266-281.

Schuemie, M. J. and et al. 2005. “The Effect of Locomotion Technique on Presence, Fear and Usability in a Virtual Environment.” Proceedings of “Euromedia 2005,” held in Toulouse, France, April 11-13, 129-135.

Schuemie, M. J. and et al. 2001. “Research on Presence in Virtual Reality: A Survey,” *CyberPsychology & Behavior* 4(2): 183-201.

Schulenberg, S. E. and A. M. A. Melton. 2008. “The Computer Aversion, Attitudes, and Familiarity Index (CAAFI): A Validity Study,” *Computers in Human Behavior* 24: 2620-2638.

Schulenberg, S. E., B. A. Yutrzenka and C. L. Gohm. 2006. “The Computer Aversion, Attitudes, and Familiarity Index (CAAFI): A Measure for the Study of Computer-Related Constructs,” *Journal of Educational Computing Research* 34(2): 129-146.

Sholl, M. J. 1988. “The Relation between Sense of Direction and Mental Geographic Updating,” *Intelligence* 12: 299-314.

Sholl, M. J and et al. 2000. “The Relation of Sex and Sense of Direction to Spatial Orientation in an Unfamiliar Environment,” *Journal of Experimental Psychology* 20: 17-28.

Skalski, P. and R. Tamborini. 2007. “The Role of Social Presence in Interactive Agent-Based Persuasion,” *Media Psychology* 10: 385-413.

Slater, M. and A. Steed. 2000. “A Virtual Presence Counter,” *Presence: Teleoperators and Virtual Environments* 9(5): 413-434.

Slater, M. and S. Wilbur. 1997. "A Framework for Immersive Virtual Environments (FIVE): Speculations on the Role of Presence in Virtual Environments," *Presence: Teleoperators and Virtual Environments* 6: 603-616.

Smith, B. and et al. 1999. "A Review of the Construct of Computer Experience," *Computers in Human Behavior* 15: 227-242.

Smith, B., P. Caputi P and P. Rawstone. 2000. "Differentiating Computer Experience and Attitudes Toward Computers: An Empirical Investigation," *Computers in Human Behavior* 16: 59-81.

Soeda, M., N. Kushiyama and R. Ohno. 1997. "Wayfinding in Cases with Vertical Motion." Proceedings of "MERA 97: International Conference on Environment-Behavior Studies," held in Tokyo, Japan, 559-564.

Spence, I. and J. Feng. 2010. "Video Games and Spatial Cognition," *Review of General Psychology* 14(2): 92-104.

Spence, I. and et al. 2009. "Women Match Men When Learning a Spatial Skill," *Journal of Experimental Psychology: Learning, Memory, and Cognition* 35: 1097-1103.

Spiers, H. J. and E. A. Maguire. 2008. "The Dynamic Nature of Cognition During Wayfinding," *Journal of Environmental Psychology* 28: 232-249.

Suma, E. A. and et al. 2010. "Effects of Travel Technique and Gender on a Divided Attention Task in a Virtual Environment." Proceedings of the "2010 IEEE Symposium on 3D User Interfaces" held in Waltham, MA, USA, March 20-21, 27-34.

Sun, C. 2009. "Architectural Cue in Evacuation Simulation for Underground Space Design." Unpublished doctoral dissertation. Eindhoven: Eindhoven University of Technology. Retrieved March 31, 2010, from http://alexandria.tue.nl/extra2/200910173.pdf.

Sun, C. and B. de Vries. 2009. "Automated Human Choice Extraction for Evacuation Route Prediction," *Automation in Construction* 18: 751-761.

Sun, C., B. de Vries and Q. Zhao. 2008. “Measure the Evacuees’ Preference on Architectural Cues by CAVE.” Proceedings of “DDSS 2008,” held in The Netherlands, July 7-10, 1-15.

Tang, C.-H., W.-T Wu and C.-H. Lin. 2009. “Using Virtual Reality to Determine How Emergency Signs Facilitate Way-Finding,” *Applied Ergonomics* 40: 722-730.

Tekinarslan, E. 2008. “Computer Anxiety: A Cross-Cultural Comparative Study of Dutch and Turkish University Students,” *Computers in Human Behavior* 24: 1572-1584.

Tenbrink, T. and J. M. Wiener. 2007. “Wayfinding Strategies in Behavior and Language: A Symmetric and Interdisciplinary Approach to Cognitive Processes.” In T. Barkowsky and et al., eds., *Spatial Cognition V*. Berlin Heidelberg: Springer-Verlag, 401-420.

Teo, T. 2008. “Assessing the Computer Attitudes of Students: An Asian Perspective,” *Computers in Human Behavior* 24: 1634-1642.

Terlecki, M. S. and N. S. Newcombe. 2005. “How Important is the Digital Divide? The Relation of Computer and Videogame Usage to Gender Differences in Mental Rotation Ability,” *Sex Roles* 53: 433-441.

Thornson, C. A., B. F. Goldiez and H. Le. 2009. “Predicting Presence: Constructing the Tendency Towards Presence Inventory,” *International Journal of Human-Computer Studies* 67: 62-78.

Tlauka, M. and et al. 2005. “Gender Differences in Spatial Knowledge Acquired Through Simulated Exploration of a Virtual Shopping Centre,” *Journal of Environmental Psychology* 25: 111-118.

Vinson, N. G. 1999. “Design Guidelines for Landmarks to Support Navigation in Virtual Environments.” Proceedings of “CHI ’99,” held in Pittsburgh, Pennsylvania, USA, May 15-20, 1-9.

Voyer, D. and et al. 2007. “Gender Differences in Object-Location Memory: A Meta-Analysis,” *Psychonomic Bulletin & Review* 14(1): 23-38.

Waller, D. 2000. “Individual Differences in Spatial Learning from Computer-Simulated Environments,” *Journal of Environmental Psychology* 25: 111-118.

Waller, D., E. Hunt and D. Knapp. 1998. “The Transfer of Spatial Knowledge in Virtual Environment,” *Presence* 7: 129-143.

Waller, D., D. Knapp and E. Hunt. 2001. “Spatial Representations of Virtual Mazes: The Role of Visual Fidelity and Individual Differences,” *Human Factors* 43: 147-158.

Werner, S. and L. E. Schindler. 2004. “The Role of Spatial Reference Frames in Architecture Misalignment Impairs Way-Finding Performance,” *Environment and Behavior* 36(4): 461-482.

Wiener, J. and H. Mallot. 2003. “Fine-to-Coarse Route Planning and Navigation in Regionalized Environments,” *Spatial Cognition and Computation* 3: 331-358.

Wiener, J. M., A. Schnee and H. A. Mallot. 2004. “Use and Interaction of Navigation Strategies in Regionalized Environments,” *Journal of Environmental Psychology* 24: 475-493.

Wilson, P. N., N. Foreman and M. Tlauka. 1997. “Transfer of Spatial Information from a Virtual to a Real Environment,” *Human Factors* 39: 526-531.

Wissmath, B. and et al. 2011. “Being Present in More than One Place at a Time? Patterns of Mental Self-Localization. *Consciousness and Cognition* 20: 1808-1815.

Witmer, B. G. and M. J. Singer. 1998. “Measuring Presence in Virtual Environments: A Presence Questionnaire,” *Presence: Teleoperators and Virtual Environments* 7(3): 225-240.

Youngblut, C. and B. M. Perrin. 2002. “Investigating the Relationship between Presence and Performance in Virtual Environments.” Paper presented at “IMAGE 2002 Conference,” held in Arizona, USA, June 8-12.

Zacharias, J. 2006. “Exploratory Spatial Behavior in Real and Virtual Environments,” *Landscape and Urban Planning* 78: 1-13.

Zhang, X. 2008. “A Multiscale Progressive Model on Virtual Navigation,” *International Journal of Human-Computer Studies* 66(4): 243-256.

APPENDIX A:

Santa Barbara Sense of Direction Scale (SBSOD)

Name:

Female ☐ Male ☐ Age:

This questionnaire consists of several statements about your spatial and navigational abilities, preferences, and experiences. After each statement, you should circle a number to indicate your level of agreement with the statement. Circle "1" if you strongly agree that the statement applies to you, "7" if you strongly disagree, or some number in between, if your agreement is intermediate. Circle "4" if you neither agree nor disagree.

	strongly agree						strongly disagree
1. I am very good at giving directions	1	2	3	4	5	6	7
2. I have a poor memory for where I left things	1	2	3	4	5	6	7
3. I am very good at judging distances.	1	2	3	4	5	6	7
4. My "sense of direction" is very good.	1	2	3	4	5	6	7
5. I tend to think of my environment in terms of cardinal directions (N, S, E, W).	1	2	3	4	5	6	7
6. I very easily get lost in a new city.	1	2	3	4	5	6	7
7. I enjoy reading maps.	1	2	3	4	5	6	7
8. I have trouble understanding directions.	1	2	3	4	5	6	7
9. I am very good at reading maps.	1	2	3	4	5	6	7
10. I do not remember routes very well while riding as a passenger in a car.	1	2	3	4	5	6	7
11. I do not enjoy giving directions.	1	2	3	4	5	6	7
12. It is not important to me to know where I am.	1	2	3	4	5	6	7
13. I usually let someone else do the navigational planning for long trips.	1	2	3	4	5	6	7
14. I can usually remember a new route after I have travelled it only once.	1	2	3	4	5	6	7
15. I do not have a very good "mental map" of my environment.	1	2	3	4	5	6	7

Items 2, 6, 8, 10-13 and 15 are reverse scored.

APPENDIX B:

The Computer Aversion, Attitudes, and Familiarity Index (CAAFI)

Below is a list of items describing many of the thoughts and experiences that people have with computers. After reading each statement, circle the number that best describes how true or how false the statement is as it applies to you at the time. If you have no opinion about the item, circle "0", but please use this option only if it is absolutely necessary. Be sure to circle only one number. Please do your best to respond to each item.

1. I enjoy using computers

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

2. Being able to use a computer is important to me.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

3. I keep up with the latest computer hardware.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

4. Computers are beneficial because they save people time.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

5. I like using word-processing programs.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

6. I feel like a fool when I am using a computer and others are around.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

7. I am smart enough to use a computer.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

8. I avoid using computers whenever possible.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

9. I do not understand how to use computer software (e.g., word-processing programs, spreadsheet programs, etc.).

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

10. I feel that I understand how to use computer files, documents, and folders.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

11. I use a computer input device every day (e.g., a keyboard, a touch pad, a mouse).

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

12. I can use a computer to successfully perform tasks.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

13. I can add new hardware to a computer.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

14. I enjoy reading computer magazines.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

15. When I use a computer, I am afraid that I will damage it.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

16. I enjoy connecting new computer accessories.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

17. I must have a reference manual or a help file to run computer software.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

18. E-mail is an easy way to communicate with people.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

19. I use e-mail every day.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

20. I am comfortable changing (installing/upgrading) computer software.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

21. I often read computer books.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

22. My friends often ask me computer-related questions.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

23. I often read computer magazines.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

24. Overall, I feel that I don't know how to use a computer.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

25. Computers are too scientific for me.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

26. When using a computer, I often lose data.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

27. I enjoy learning to use new software programs.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

28. I like to use computer input devices such as a keyboard, a touch pad, a mouse.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

29. Using a computer is entertaining.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

30. I keep up with the latest computer software.

-3	-2	-1	0	1	2	3
Absolutely false			Neutral			Absolutely true

Items 6, 8, 9, 15, 17, 24, 25 and 26 are reverse scored.
Computer Familiarity: Items 3, 13-14, 16, 20-23, 27 and 30.
Computer Attitudes: Items 1-2, 4-5, 8, 11, 18-19 and 28-29.
Computer Aversion: Items 6-7, 9-10, 12, 15, 17 and 24-26.

APPENDIX C:

Observation Sheet

1. Name: Female ☐ Male ☐
2. Age:
3. Left-handed ☐ Right-handed ☐

SET 1: *Wegame No:* *Total Duration:*

1. Order of Room Visits: <u>Left</u> <u>Middle</u> <u>Right</u>

2. Preferred Up Stairs: A (Left) ☐ B (Middle) ☐
3. Why? ....
4. Duration of navigation on ground floor:

5. Order of Room Visits: <u>Left</u> <u>Middle</u> <u>Right</u>

6. Preferred Down Stairs: A (Left) ☐ B (Middle) ☐
7. Why? ....
8. Duration of navigation on first floor:

SET 2: *Wegame No:* *Total Duration:*

1. Order of Room Visits: <u>Left</u> <u>Middle</u> <u>Right</u>

2. Preferred Up Stairs: A (Left) ☐ C (Right) ☐
3. Why? ....
4. Duration of navigation on ground floor:

5. Order of Room Visits: <u>Left</u> <u>Middle</u> <u>Right</u>

6. Preferred Down Stairs: A (Left) ☐ C (Right) ☐
7. Why? ....
8. Duration of navigation on first floor:

APPENDIX D:

Igroup Presence Questionnaire (IPQ) and

Computer Experience Questionnaire

Name:

Part A: Igroup Presence Questionnaire (IPQ)
Please rate the following questions according to your experience in the virtual environment.

1. In the computer generated world I had a sense of "being there"

-3	-2	-1	0	1	2	3
not at all						very much

2. Somehow I felt that the virtual world surrounded me.

-3	-2	-1	0	1	2	3
fully disagree						fully agree

3. I felt like I was just perceiving pictures.

-3	-2	-1	0	1	2	3
fully disagree						fully agree

4. I did not feel present in the virtual space.

-3	-2	-1	0	1	2	3
did not feel						felt present

5. I had a sense of acting in the virtual space, rather than operating something from outside.

-3	-2	-1	0	1	2	3
fully disagree						fully agree

6. I felt present in the virtual space.

-3	-2	-1	0	1	2	3
fully disagree						fully agree

7. How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?

-3	-2	-1	0	1	2	3
extremely aware			moderately aware			not aware at all

8. I was not aware of my real environment.

-3	-2	-1	0	1	2	3
fully disagree						fully agree

9. I still paid attention to the real environment.

-3	-2	-1	0	1	2	3
fully disagree						fully agree

10. I was completely captivated by the virtual world.

-3	-2	-1	0	1	2	3
fully disagree						fully agree

11. How real did the virtual world seem to you?

-3	-2	-1	0	1	2	3
completely real						not real at all

12. How much did your experience in the virtual environment seem consistent with your real world experience?

-3	-2	-1	0	1	2	3
not consistent			moderately consistent			very consistent

13. How real did the virtual world seem to you?

-3	-2	-1	0	1	2	3
about as real as an imagined world						indistinguishable from the real world

14. The virtual world seemed more realistic than the real world.

-3	-2	-1	0	1	2	3
fully disagree						fully agree

Part B:

1. Did you hear about Second Life before? Yes ☐ No ☐

2. a. Did you use Second Life before? Yes ☐ No ☐

   b. If yes, how often do you use SL? …………………………….

3. a. Do you play computer games Yes ☐ No ☐

   b. If yes, how often do you play computer games?

   Less than once in a week ☐ Once in a week ☐ More than once in a week ☐

   c. How long have you been playing computer games? ……………………

   d. Please list the computer games that you play

   1. …………………………………
   2. …………………………………
   3. …………………………………
   4. …………………………………

APPENDIX E:

Statistical Analysis

Table E1. Paired Samples Test for Set 1

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Stairs1up - Stairs1down	-,033	,678	,071	-,175	,109	-,466	89	,642

Table E2. Paired Samples Correlations Test for Set 1

		N	Correlation	Sig.
Pair 1	Stairs1up & Stairs1down	90	,000	1,000

Table E3. Paired Samples Test for Set 2

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Stairs1up - Stairs1down	-,244	1,230	,130	-,502	,013	-1,886	89	,063

Table E4. Chi-Square Test between First Visited Room and Staircase Preference – Ascending for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)
Set 1	Pearson Chi-Square	3,019[a]	2	,221
	Likelihood Ratio	3,229	2	,199
	Linear-by-Linear Association	1,336	1	,248
	N of Valid Cases	90		
Set 2	Pearson Chi-Square	15,817[b]	2	,000
	Likelihood Ratio	16,649	2	,000
	Linear-by-Linear Association	15,641	1	,000
	N of Valid Cases	90		

a. 2 cells (33,3%) have expected count less than 5. The minimum expected count is 2,57.

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 7,93.

Table E5. Independent Samples Test for First Visited Rooms 1 & 2 and Staircase Preference – Ascending in Set 2

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Stairs1up	Equal variances assumed	16,195	,000	1,856	42	,071	,536	,289	-,047	1,119
	Equal variances not assumed			1,966	40,024	,056	,536	,273	-,015	1,087

Table E6. Independent Samples Test for Staircase Preferences – Ascending according to Circulation Path in Set 1

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
RVisitStart11	Equal variances assumed	1,359	,247	1,158	88	,250	,244	,211	-,175	,663
	Equal variances not assumed			1,143	64,362	,257	,244	,213	-,182	,670
LastRoomVisit11	Equal variances assumed	2,452	,121	-,719	88	,474	-,139	,193	-,522	,245
	Equal variances not assumed			-,741	73,127	,461	-,139	,187	-,512	,235

Table E7. Chi-Square Test between Last Visited Room and Staircase Preference – Ascending in Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)
Set 1	Pearson Chi-Square	3,492[a]	2	,174
	Likelihood Ratio	3,459	2	,177
	Linear-by-Linear Association	,520	1	,471
	N of Valid Cases	90		
Set 2	Pearson Chi-Square	8,510[b]	2	,014
	Likelihood Ratio	8,638	2	,013
	Linear-by-Linear Association	7,093	1	,008
	N of Valid Cases	90		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 7,70.

b. 2 cells (33,3%) have expected count less than 5. The minimum expected count is 3,27.

Table E8. Independent Samples Test for Last Visited Rooms 1 & 2 and Staircase Preference – Ascending in Set 2

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Stairs1up	Equal variances assumed	,394	,533	-1,944	58	,057	-,749	,385	-1,521	,022
	Equal variances not assumed			-1,914	7,604	,094	-,749	,392	-1,660	,162

Table E9. Independent Samples Test for Last Visited Rooms 2 & 3 and Staircase Preference – Ascending in Set 2

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Stairs1up	Equal variances assumed	,830	,368	,394	35	,696	,162	,411	-,673	,997
	Equal variances not assumed			,395	9,054	,702	,162	,410	-,765	1,089

Table E10. Chi-Square Tests between Gender and SBSOD Scores for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	5,421[b]	1	,020		
	Continuity Correction [a]	4,480	1	,034		
	Likelihood Ratio	5,478	1	,019		
	Fisher's Exact Test				,034	,017
	Linear-by-Linear Association	5,360	1	,021		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	2,846[c]	1	,092		
	Continuity Correction [a]	2,179	1	,140		
	Likelihood Ratio	2,861	1	,091		
	Fisher's Exact Test				,140	,070
	Linear-by-Linear Association	2,814	1	,093		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 20,50.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 22,00.

Table E11. Distribution of the IPQ Scores according to Gender

	General Item		Spatial Presence		Involvement		Realness	
Gender	P	G	P	G	P	G	P	G
Female	28	62	38	52	40	50	44	46
Male	19	71	45	45	45	45	39	51
Total	47	133	83	97	85	95	83	97

Table E12. Chi-Square Test between Gender and General Item Factor for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	1,866[b]	1	,172		
	Continuity Correction[a]	1,296	1	,255		
	Likelihood Ratio	1,877	1	,171		
	Fisher's Exact Test				,255	,127
	Linear-by-Linear Association	1,846	1	,174		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	,600[c]	1	,438		
	Continuity Correction[a]	,267	1	,605		
	Likelihood Ratio	,602	1	,438		
	Fisher's Exact Test				,606	,303
	Linear-by-Linear Association	,594	1	,441		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 14,00.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 9,50.

Table E13. Chi-Square Test between Gender and Spatial Presence Factor for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	,045[b]	1	,833		
	Continuity Correction[a]	,000	1	1,000		
	Likelihood Ratio	,045	1	,833		
	Fisher's Exact Test				1,000	,500
	Linear-by-Linear Association	,044	1	,834		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	1,667[c]	1	,197		
	Continuity Correction[a]	1,157	1	,282		
	Likelihood Ratio	1,673	1	,196		
	Fisher's Exact Test				,282	,141
	Linear-by-Linear Association	1,648	1	,199		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 21,50.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 18,00.

Table E14. Chi-Square Test between Gender and Involvement Factor for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	,711[b]	1	,399		
	Continuity Correction[a]	,400	1	,527		
	Likelihood Ratio	,712	1	,399		
	Fisher's Exact Test				,527	,264
	Linear-by-Linear Association	,704	1	,402		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	,045[c]	1	,832		
	Continuity Correction[a]	,000	1	1,000		
	Likelihood Ratio	,045	1	,832		
	Fisher's Exact Test				1,000	,500
	Linear-by-Linear Association	,044	1	,833		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 22,00.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 20,50.

Table E15. Chi-Square Test between Gender and Realness Factor for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	1,113[b]	1	,291		
	Continuity Correction[a]	,713	1	,399		
	Likelihood Ratio	1,116	1	,291		
	Fisher's Exact Test				,399	,199
	Linear-by-Linear Association	1,101	1	,294		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	,000[c]	1	1,000		
	Continuity Correction[a]	,000	1	1,000		
	Likelihood Ratio	,000	1	1,000		
	Fisher's Exact Test				1,000	,585
	Linear-by-Linear Association	,000	1	1,000		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 21,50.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 18,00.

Table E16. Chi-Square Tests between Gender and Computer Familiarity Scores for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	18,000[b]	1	,000		
	Continuity Correction[a]	16,245	1	,000		
	Likelihood Ratio	18,693	1	,000		
	Fisher's Exact Test				,000	,000
	Linear-by-Linear Association	17,800	1	,000		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	,045[c]	1	,833		
	Continuity Correction[a]	,000	1	1,000		
	Likelihood Ratio	,045	1	,833		
	Fisher's Exact Test				1,000	,500
	Linear-by-Linear Association	,044	1	,834		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 20,00.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 21,50.

Table E17. Chi-Square Test between Gender and Frequency of Playing Computer for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)
Set 1	Pearson Chi-Square	16,972[a]	2	,000
	Likelihood Ratio	17,581	2	,000
	Linear-by-Linear Association	13,043	1	,000
	N of Valid Cases	74		
Set 2	Pearson Chi-Square	,420[b]	2	,810
	Likelihood Ratio	,421	2	,810
	Linear-by-Linear Association	,151	1	,698
	N of Valid Cases	78		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 6,24.

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 10,03.

Table E18. Independent Sample Test for Gender and Computer Usage for Set 2

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PlayGame	Equal variances assumed	52,987	,000	3,021	88	,003	,222	,074	,076	,368
	Equal variances not assumed			3,021	62,250	,004	,222	,074	,075	,369
Frequency	Equal variances assumed	,225	,637	-,386	76	,701	-,075	,194	-,461	,312
	Equal variances not assumed			-,384	69,586	,702	-,075	,195	-,464	,314
Play Computer	Equal variances assumed	3,181	,078	-4,553	76	,000	-1,071	,235	-1,539	-,602
	Equal variances not assumed			-4,388	59,095	,000	-1,071	,244	-1,559	-,583
PlayShooting	Equal variances assumed	11,963	,001	4,785	76	,000	,483	,101	,282	,683
	Equal variances not assumed			4,918	75,835	,000	,483	,098	,287	,678

Table E19. Chi-Square Test between Gender and Starting Room Preferences for Ground Floors of Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)
Set 1	Pearson Chi-Square	4,811[a]	2	,090
	Likelihood Ratio	5,207	2	,074
	Linear-by-Linear Association	,966	1	,326
	N of Valid Cases	90		
Set 2	Pearson Chi-Square	2,847[b]	2	,241
	Likelihood Ratio	2,862	2	,239
	Linear-by-Linear Association	2,230	1	,135
	N of Valid Cases	90		

a. 2 cells (33,3%) have expected count less than 5. The minimum expected count is 3,50.

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 8,50.

Table E20. Chi-Square Test between Gender and Starting Room Preferences for First Floors of Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)
Set 1	Pearson Chi-Square	,359[a]	2	,836
	Likelihood Ratio	,365	2	,833
	Linear-by-Linear Association	,011	1	,915
	N of Valid Cases	90		
Set 2	Pearson Chi-Square	3,443[b]	2	,179
	Likelihood Ratio	3,492	2	,174
	Linear-by-Linear Association	1,116	1	,291
	N of Valid Cases	90		

a. 2 cells (33,3%) have expected count less than 5. The minimum expected count is 1,50.

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 7,50.

Table E21. Chi-Square Test between Gender and Direction of Navigation for Ground Floors of Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	,045[b]	1	,832		
	Continuity Correction[a]	,000	1	1,000		
	Likelihood Ratio	,045	1	,832		
	Fisher's Exact Test				1,000	,500
	Linear-by-Linear Association	,044	1	,833		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	,051[c]	1	,822		
	Continuity Correction[a]	,000	1	1,000		
	Likelihood Ratio	,051	1	,822		
	Fisher's Exact Test				1,000	,500
	Linear-by-Linear Association	,050	1	,823		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 20,50.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 14,50.

Table E22. Chi-Square Test between Gender and Direction of Navigation for First Floors of Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	,009[b]	1	,925		
	Continuity Correction[a]	,000	1	1,000		
	Likelihood Ratio	,009	1	,925		
	Fisher's Exact Test				1,000	,548
	Linear-by-Linear Association	,009	1	,925		
	N of Valid Cases	87				
Set 2	Pearson Chi-Square	2,820[c]	1	,093		
	Continuity Correction[a]	2,078	1	,149		
	Likelihood Ratio	2,854	1	,091		
	Fisher's Exact Test				,104	,074
	Linear-by-Linear Association	2,783	1	,095		
	N of Valid Cases	75				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 18,78.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 13,53.

Table E23. Chi-Square Test between Gender and Staircase Preferences - Ascending for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	1,196[b]	1	,274		
	Continuity Correction[a]	,766	1	,382		
	Likelihood Ratio	1,200	1	,273		
	Fisher's Exact Test				,382	,191
	Linear-by-Linear Association	1,183	1	,277		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	2,857[c]	1	,091		
	Continuity Correction[a]	2,188	1	,139		
	Likelihood Ratio	2,873	1	,090		
	Fisher's Exact Test				,139	,069
	Linear-by-Linear Association	2,825	1	,093		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 16,50.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 21,00.

Table E24. Chi-Square Test between Gender and Staircase Preferences - Descending for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	1,800[b]	1	,180		
	Continuity Correction[a]	1,250	1	,264		
	Likelihood Ratio	1,809	1	,179		
	Fisher's Exact Test				,263	,132
	Linear-by-Linear Association	1,780	1	,182		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	7,756[c]	1	,005		
	Continuity Correction[a]	6,609	1	,010		
	Likelihood Ratio	7,888	1	,005		
	Fisher's Exact Test				,010	,005
	Linear-by-Linear Association	7,670	1	,006		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 15,00.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 18,50.

Table E25. Chi-Square Test between SOD and Staircase Preferences – Ascending for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	,180[b]	1	,671		
	Continuity Correction[a]	,042	1	,838		
	Likelihood Ratio	,180	1	,671		
	Fisher's Exact Test				,826	,418
	Linear-by-Linear Association	,178	1	,673		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	,420[c]	1	,517		
	Continuity Correction[a]	,191	1	,662		
	Likelihood Ratio	,420	1	,517		
	Fisher's Exact Test				,534	,331
	Linear-by-Linear Association	,415	1	,519		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 15,03.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 20,53.

Table E26. Chi-Square Test between SOD and Staircase Preferences – Descending for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	,090[b]	1	,765		
	Continuity Correction[a]	,006	1	,940		
	Likelihood Ratio	,090	1	,765		
	Fisher's Exact Test				,825	,471
	Linear-by-Linear Association	,089	1	,766		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	,218[c]	1	,641		
	Continuity Correction[a]	,064	1	,801		
	Likelihood Ratio	,218	1	,641		
	Fisher's Exact Test				,673	,401
	Linear-by-Linear Association	,215	1	,643		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 13,67.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 18,09.

Table E27. Chi-Square Test between Sense of Presence and Staircase Preferences – Ascending for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	,956[b]	1	,328		
	Continuity Correction[a]	,576	1	,448		
	Likelihood Ratio	,957	1	,328		
	Fisher's Exact Test				,384	,224
	Linear-by-Linear Association	,946	1	,331		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	,007[c]	1	,931		
	Continuity Correction[a]	,000	1	1,000		
	Likelihood Ratio	,007	1	,931		
	Fisher's Exact Test				1,000	,551
	Linear-by-Linear Association	,007	1	,932		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 15,77.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 16,80.

Table E28. Chi-Square Test between Sense of Presence and Staircase Preferences – Descending for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	,022[b]	1	,881		
	Continuity Correction[a]	,000	1	1,000		
	Likelihood Ratio	,022	1	,881		
	Fisher's Exact Test				1,000	,530
	Linear-by-Linear Association	,022	1	,882		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	,926[c]	1	,336		
	Continuity Correction[a]	,553	1	,457		
	Likelihood Ratio	,923	1	,337		
	Fisher's Exact Test				,386	,228
	Linear-by-Linear Association	,915	1	,339		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 14,33.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 14,80.

Table E29. Chi-Square Test between Computer Familiarity and Staircase Preferences – Ascending for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	1,055[b]	1	,304		
	Continuity Correction[a]	,651	1	,420		
	Likelihood Ratio	1,053	1	,305		
	Fisher's Exact Test				,380	,210
	Linear-by-Linear Association	1,043	1	,307		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	,669[c]	1	,413		
	Continuity Correction[a]	,368	1	,544		
	Likelihood Ratio	,669	1	,413		
	Fisher's Exact Test				,526	,272
	Linear-by-Linear Association	,661	1	,416		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 14,67.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 20,07.

Table E30. Chi-Square Test between Computer Familiarity and Staircase Preferences – Descending for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Set 1	Pearson Chi-Square	,023[b]	1	,881		
	Continuity Correction[a]	,000	1	1,000		
	Likelihood Ratio	,023	1	,881		
	Fisher's Exact Test				1,000	,531
	Linear-by-Linear Association	,022	1	,881		
	N of Valid Cases	90				
Set 2	Pearson Chi-Square	,085[c]	1	,771		
	Continuity Correction[a]	,006	1	,939		
	Likelihood Ratio	,085	1	,771		
	Fisher's Exact Test				,832	,470
	Linear-by-Linear Association	,084	1	,773		
	N of Valid Cases	90				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 13,33.

c. 0 cells (,0%) have expected count less than 5. The minimum expected count is 17,68.

Table E31. Chi-Square Test between Frequency of Playing Computer Games and Staircase Preferences – Ascending for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)
Set 1	Pearson Chi-Square	,284[a]	2	,868
	Likelihood Ratio	,288	2	,866
	Linear-by-Linear Association	,073	1	,786
	N of Valid Cases	74		
Set 2	Pearson Chi-Square	,168[b]	2	,919
	Likelihood Ratio	,169	2	,919
	Linear-by-Linear Association	,149	1	,700
	N of Valid Cases	78		

a. 1 cells (16,7%) have expected count less than 5. The minimum expected count is 4,73.

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 9,73.

Table E32. Chi-Square Test between Frequency of Playing Computer Games and Staircase Preferences – Descending for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)
Set 1	Pearson Chi-Square	8,969[a]	2	,011
	Likelihood Ratio	9,124	2	,010
	Linear-by-Linear Association	5,953	1	,015
	N of Valid Cases	74		
Set 2	Pearson Chi-Square	2,238[b]	2	,327
	Likelihood Ratio	2,250	2	,325
	Linear-by-Linear Association	,863	1	,353
	N of Valid Cases	78		

a. 1 cells (16,7%) have expected count less than 5. The minimum expected count is 4,73.

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 10,32.

Table E33. Chi-Square Test between Playing Computer Games in Years and Staircase Preferences – Ascending for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)
Set 1	Pearson Chi-Square	,189[a]	3	,979
	Likelihood Ratio	,192	3	,979
	Linear-by-Linear Association	,115	1	,735
	N of Valid Cases	74		
Set 2	Pearson Chi-Square	2,119[b]	3	,548
	Likelihood Ratio	2,194	3	,533
	Linear-by-Linear Association	,392	1	,531
	N of Valid Cases	78		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 5,74.

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 5,50.

Table E34. Chi-Square Test between Playing Computer Games in Years and Staircase Preferences – Descending for Set 1 and Set 2

Set		Value	df	Asymp. Sig. (2-sided)
Set 1	Pearson Chi-Square	5,803[a]	3	,122
	Likelihood Ratio	5,893	3	,117
	Linear-by-Linear Association	5,621	1	,018
	N of Valid Cases	74		
Set 2	Pearson Chi-Square	7,381[b]	3	,061
	Likelihood Ratio	7,515	3	,057
	Linear-by-Linear Association	4,510	1	,034
	N of Valid Cases	78		

a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 5,74.

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 5,83.

Table E35. Independent Samples Test for Computer Game Usage (Once in a week & More than once in a week) and Staircase Preferences – Descending for Set 1

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Stairs1down	Equal variances assumed	2,127	,152	,681	42	,500	,090	,133	-,178	,359
	Equal variances not assumed			,725	29,862	,474	,090	,125	-,165	,346

Table E36. Independent Samples Test for Virtual Navigation Total Duration

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
TDuration11	Equal variances assumed	,586	,445	1,549	178	,123	,256	,165	-,070	,581
	Equal variances not assumed			1,549	177,570	,123	,256	,165	-,070	,581

APPENDIX F:

Screenshots of the Desktop VE

Set 1:

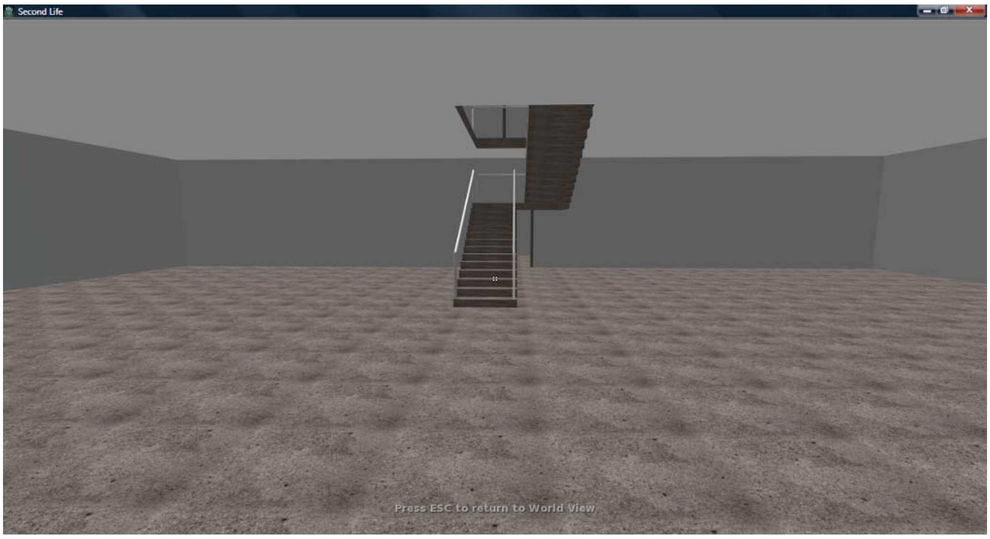

Figure F1. A view from the entrance

Figure F2. A view from the entrance looking to the left

Figure F3. A view from the entrance looking to the right

Figure F4. A view from Room 1

Figure F5. A view from Room 2

Figure F6. A view from Room 3

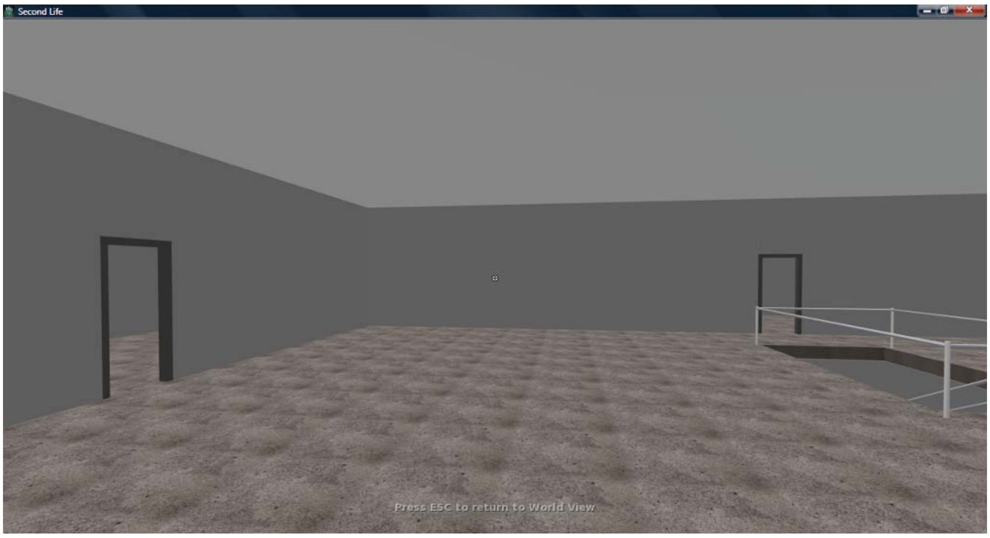

Figure F7. A view from Staircase A looking towards Rooms 4 & 5

Figure F8. A view from Staircase A looking towards Rooms 5 & 6

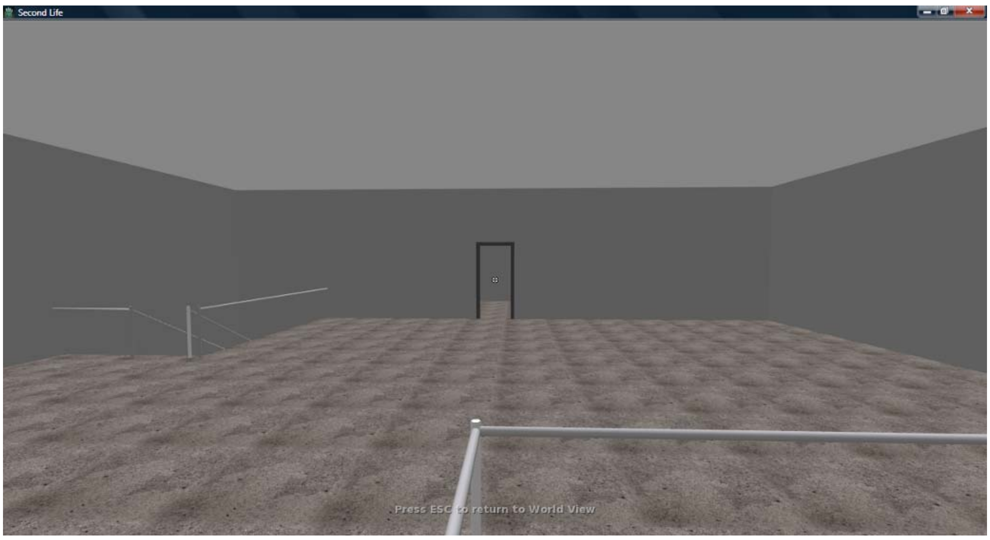

Figure F9. A view from Staircase B looking towards Room 4

Figure F10. A view from Staircase B looking towards Room 5

Figure F11. A view from Staircase B looking towards Room 6

Figure F12. A view from Room 4

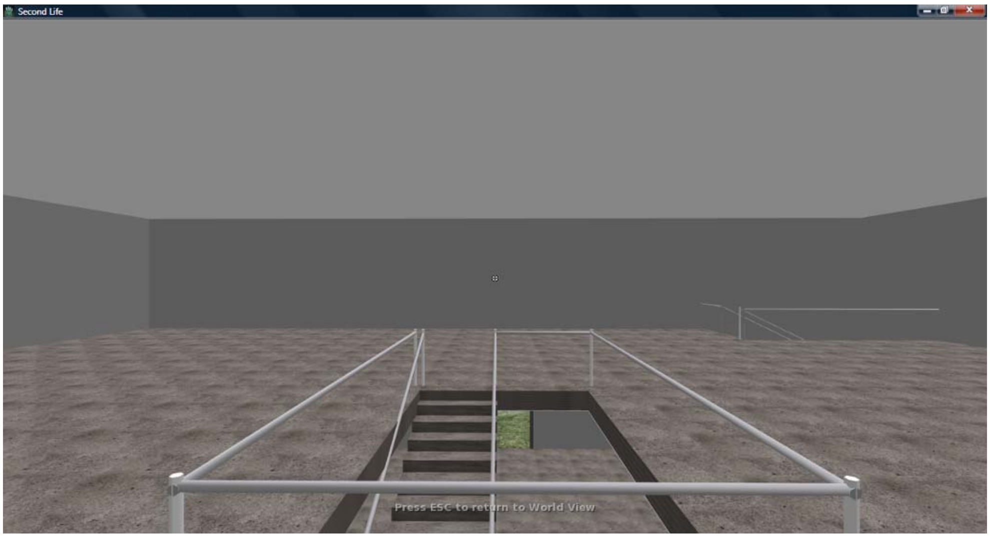

Figure F13. A view from Room 5

Figure F14. A view from Room 6

Figure F15. A view from the right corner of the VE

Set 2:

Figure F16. A view from the entrance

Figure F17. A view from the entrance looking to the left

Figure F18. A view from the entrance looking towards Room 1 and Staircase A

Figure F19. A view from the entrance looking to the right

Figure F20. A view from the entrance looking towards Room 3 and Staircase C

Figure F21. A view from Room 1

Figure F22. A view from Room 1 looking towards the entrance

Figure F23. A view from Room 2

Figure F24. A view from Room 3

Figure F25. A view from Room 3 looking towards the entrance

Figure F26. A view from Staircase A

Figure F27. A view from Staircase C

Figure F28. A view from Room 4

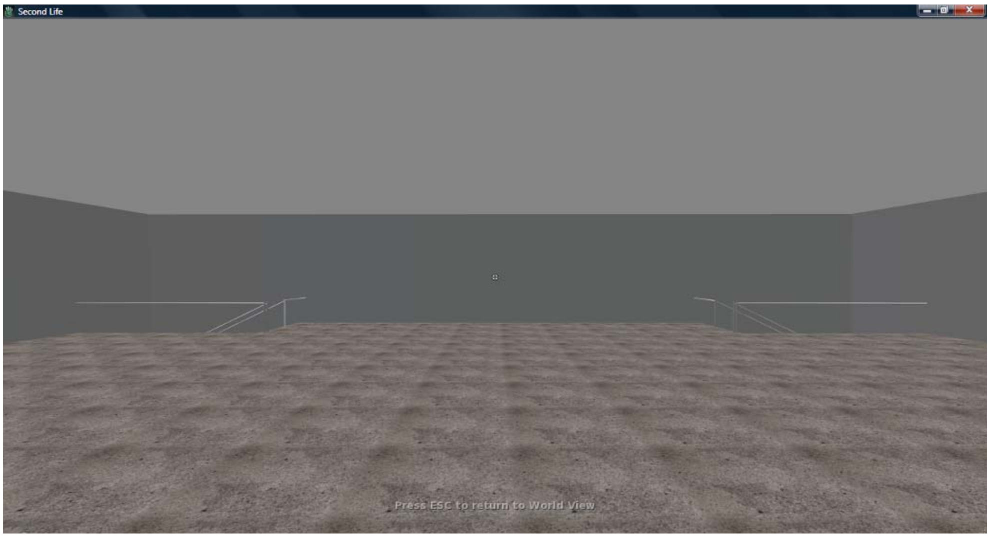

Figure F29. A view from Room 5

Figure 30. A view from Room 6

Figure F31. View of the gift box