THE ROLE OF ATTENTION FOR VISUAL PERCEPTION IN DESKTOP VIRTUAL REALITY ENVIRONMENTS

A THESIS SUBMITTED TO

THE GRADUATE SCHOOL OF INFORMATICS

OF

THE MIDDLE EAST TECHNICAL UNIVERSITY

BY

HACER UKE

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

THE DEPARTMENT OF COGNITIVE SCIENCE

MAY 2005

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this wok.

Name, Last name : HACER ÜKE

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my gratitude to my supervisor Asst.Prof.Dr.Kürşat Çağıltay and my co-supervisor Prof.Dr.H.Gürkan Tekman for their guidance and support during the course of my masters. I am also grateful to other members of my committee, Prof.Dr.Neşe Yalabık and Asst.Prof.Dr.Bilge Say for taking the time to read my thesis and provide excellent comments for its improvement.

Special thanks to Assoc.Prof.Dr.Katy Börner and Assoc.Prof.Dr.Barbara Bichelmeyer from Indiana University for their help to use the IUni environment.

I wish to express my special appreciation to my brother Barış Üke and my friends; F.Cemile Hoşver, A.Serkan Şık, Yalın Baştanlar and Feza Taş for supporting me in every stage of this study.

I will be externally grateful to Cüneyt Karacan. I could never have gotten to this stage in my life without his unconditional support.

Finally, I thank all the people who helped me in anyway they could, Their names I could not mention here but their memories will be with me all the rest of my life.

ABSTRACT

THE ROLE OF ATTENTION FOR VISUAL PERCEPTION IN DESKTOP IRTUAL REALITY ENVIRONMENTS

ÜKE, Hacer

M.Sc., Department of Cognitive Science

Supervisor: Asst. Prof. Dr. Kürşat Çağıltay

Co-supervisor: Prof. Dr. Hasan Gürkan Tekman

May 2005, 88 pages

Virtual Environments are new types of human-computer interaction interfaces in which users perceive and act in a three-dimensional world. In order to examine its features, the researchers have the chance to use it both as a tool and as an experimental area for their studies. In this study, it is used as an experimental area since it is an application where perceptual information became an essential key for success. Furthermore, it is also used as a research technique, because of its ability to provide the participants with the previously unseen environment in which the experiment of the study is conducted. 60 undergraduate and graduate students participated to this study. A desktop Virtual Reality Environment was created and used to conduct the experiments. The findings showed that configurational knowledge can be attained in desktop virtual environments. In addition, it is found that visual attention has a significant role on forming cognitive maps since a secondary task caused a decrease in the performance of participants.

Keywords: Virtual reality, cognitive maps, object recognition, attention, incidental learning

CHAPTER 1

INTRODUCTION

1.1 Motivation

During the past several years, computer based virtual environments have gained wide attention. Today, we have the chance to design high quality virtual environments with the improvements in the technology of displays. In real-world cases, we perceive the environment by means of many sources of visual information such as occlusion, relative size, etc. Since the technology provides different types of sources for visual perception, the effectiveness and efficiency of visual and cognitive tasks in these simulated environments can be affected either in a positive or a negative way. In order to better understand these effects, we should examine our visual perception and the mechanisms of human cognition in virtual environments.

The motivation behind the usage of virtual reality (VR) for cognitive purposes includes two things. First thing is the ease of using virtual reality applications for examining cognitive issues for some cases that are difficult to handle in real world environments and the second one is the new perspective that the results of cognition experiments bring into the development of virtual reality technology. Furthermore, there are mainly two important questions in these type of experiments (Baker & Wickens, 1992):

- What cognitive issues lie behind each VR application
- How do these issues play into the user's perceptual strengths and weaknesses

In this study, the effects of attention were examined for cognitive map construction, memory for locations of objects and object recognition in Desktop Virtual Reality Environments.

1.2 Definitions

In order for the concepts of the thesis to be more understandable some brief definitions are given in this section. These concepts include virtual reality, attention, cognitive maps, object recognition and the discrimination between intentional and incidental learning.

1.2.1 Virtual Reality

A typical dictionary definition of the term *virtual reality* is "an image produced by a computer that surrounds that person looking at it and seems almost real" (Longman, 1995, p.1597). Here, the word *reality* refers to the *external physical world* and when it exists virtually, the reality suggests something can be explored by our senses, and yet does not physically exist. There is a general acceptance that "Virtual Reality is about creating acceptable substitutes for real objects or environments, and is not really about constructing imaginary worlds that are indistinguishable from the real world" (Vince, 1999, p.27).

Virtual Reality provides the user with images of 3D scenes and allows him/her to navigate, explore and interact with them. In order to achieve this goal, real-time graphics are required because of the need for making the user believe that they are part of a virtual domain.

Virtual Reality Environments are highly interactive and, therefore, there is a need for many types of input and output technologies. The devices that are used in virtual environments are truly interactive because they combine multisensory feedback with input from the user. In general, 3D mouse, instrumented gloves and suits are used as the input devices, which allow the user to navigate or to pick objects and communicate hand gestures to the host software within a Virtual Environment. Furthermore, glasses and displays such as 3D screens, Head-Mounted-Displays, retinal displays, CAVEs (rooms that display the virtual environment), panoramic screens and augmented realities[1] are used as the output devices.

Virtual Reality Environments have two principal variants:

- Desktop Virtual Reality
- Immersive Virtual Reality

When the 3D graphical virtual world is displayed on a standard computer screen, it is called as Desktop Virtual Reality in which PCs and workstations can be used as screen-based Virtual Reality systems. This does not give true 3D depth perception and the sense of presence[2] is low. The reason for this is because of the user's peripheral vision, which is still in the real world while using the standard PC. On the other hand, when the user has the sense of being immersed in the 3D virtual world by wearing head-mounted-displays and/or instrumented suits, the system is called as Immersive Virtual Reality in which the user sees true stereo images and true 3D depth.

In order to track the user's presence in Immersive Virtual Reality Systems, there are two aspects that need to be detected:

---

[1] Augmented Reality is the use of transparent Head Mounted Displays to overlay computer-generated images onto the physical environment. From: www.hitl.washington.edu/scivw/EVE/IV.Definitions.html

[2] Presence is the subjective perception that a mediated experience seems very much like it is not mediated. (For further reading: Slater, M (2003). A Note on Presence Terminology. *Presence-Connect*, 3 (3).)

- the user's location and motion in the real world
- the position of the user's head and limbs

In Immersive Virtual Reality, users have the chance to move around and monitoring the user's absolute position is necessary for the reflection of his/her movement in the virtual world. Sensors, which are implemented by the technologies like infrared beams and ultrasonics, are used for tracking the user's head position. This is important because of the need for the correlation between the user's motions in virtual reality and the perceived change in the virtual world.

1.2.2 Attention

Attention is one of the interesting aspects of cognitive psychology and it can be described as the process whereby a person concentrates on some parts of the environment while relatively excluding other things[3]. It is a cognitive process for selecting between the currently performed tasks [4]. For example, someone can concentrate on watching a movie on TV while ignoring the conversations in the room and only listening to those occurring in that movie. On the other hand, this is not the case all the time since attention can be divided between two or more tasks that need to be done at the same time such as talking

[3] from: www.cogsci.princeton.edu/cgi-bin/webwn2.1
[4] Cognitive Psychology Class Notes http://www.alleydog.com/cognotes/attention.html

on a cell phone while driving a car. The results of this process, i.e divided attention, is one of the concepts that was examined in this study.

1.2.3 Cognitive Maps

Humans can find their way from one location to another pre-determined, and unobservable location, within a familiar environment (Stankiewicz & Kalia, 2004). This performance can be achieved using an internal representation of the large-scale space. These internal representations of the large-scale spaces are typically referred to as cognitive maps (Tolman, 1948).

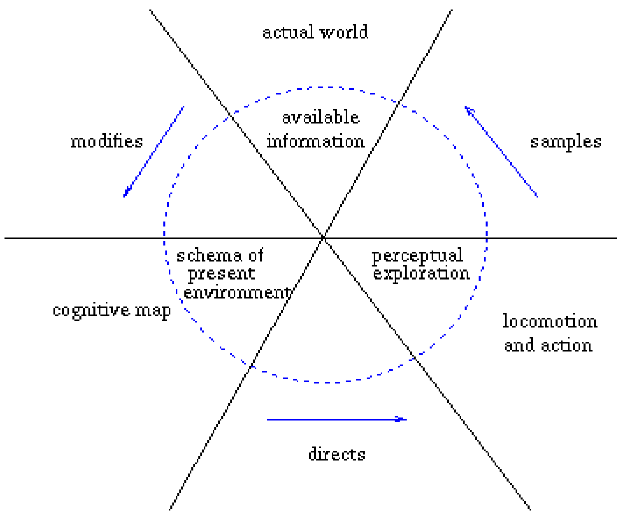


Figure 1.1 Perception - Action Cycle (Neisser, 1976)

These maps are interpretive frameworks of the world that, it is argued, exist in the human mind and affects actions and decisions as well as knowledge structures (See Figure 1.1).

1.2.4 Object Recognition

The typical dictionary definition for object recognition is the act of knowing something because you have learned about it in the past (Longman, 1995, p.1187). In addition, it can be described as the visual perception of familiar objects[5].

The task is based on the recall of perceptual characteristics of some objects, which were seen previously. In this study, object recognition was examined for different levels of allocation of attention in humans. For this task, both previously seen and unseen (i.e distracter) objects were used to test the object recognition performance of the participants.

1.2.5 Intentional vs. Incidental Learning

A different sense of learning is a relatively permanent change in capacity for performance, acquired through experience (Huitt, 2001). When the learning occurs intentionaly, there is a deliberate attempt to learn since the learner consciously studies for obtaining the desired output from the learning process. Here, the process is goal-driven and the person intends to learn certain things and sets out to do so. On the other hand, if the learner is not told in advance that he/she would be expected to come up with a specific output, then the learning occurs as a byproduct of exposure to the environment. Here, the person

[5] from: http://www.cogsci.princeton.edu/cgi-bin/webwn2.1?s=object%20recognition

responds to the environment but not actively pursues specific goals and this case is called as incidental learning (Castelhano & Henderson, 2002).

1.3 Problem Statement

This study will examine the differences in spatial learning done under different levels of allocation of visual attention in a 3D desktop VR system. The experiments of this study will investigate the following research question:

- Does visual attention change the level of spatial learning?

The expected result of this study is the proof of the importance of allocation of visual attention both for constructing a cognitive map in a person's mind and for object recognition.

1.4 Hypotheses

The results of this study test the following hypotheses.

H_1: Test scores for the *Group1* will be the highest for constructing the cognitive map of the virtual park.

H_2: Test scores for the *Group1* will be the highest for the memory for the locations of objects in desktop VR.

H_3: Test scores for the *Group1* will be the highest for object recognition in desktop VR.

H$_4$: Test scores for the *Group2* will be lower than that of Group1 for all types of performances because of having divided attention.

H$_5$: Test scores for the *Group3* will be the lowest for all types of performances.

1.5 Organization of Thesis

This chapter has described the problem addressed by this thesis in the context in which it arises, and has spelled out the hypotheses of this thesis, as well as providing a description of its contributions. The next chapter will examine the relevant literature, summarizing other studies and placing the work in context.

Chapter 3 will describe the virtual park in which the experiment of the study was conducted, emphasizing the aspects of its construction. The design of the experiment will also be discussed and the information about the participants, apparatus, procedure and measurements will be given in this chapter. Chapter 4 will examine the results of this study, examine what conclusions might be drawn, and will speculate on the future of virtual reality in visual perception applications.

CHAPTER 2

RELATED WORK

There are many research studies that have been conducted for examining the Virtual Reality Environments and a number of them are also related to cognitive psychology. In this section, related studies will be mentioned briefly.

2.1 Cognitive Map Construction

The actual maps both record what is known and remembered about an environment and act as wayfinding aids and they are used to guide travel. In the absence of these artifacts, humans and animals rely on internal representations or stored memories of experienced environments, now commonly referred to as cognitive maps (Golledge,1999). The term cognitive map was first used by Tolman (1948). He suggested that the animals, particularly the rats, appeared to be able to use spatial information as though the places they remembered were recorded in a maplike manner. The results showed that those animals had acquired a cognitive map to the effect that food was to the left and water to the right, although during the acquisition of this map they had not exhibited any stimulus-response propensities to go more to the side which became later the side of the appropriate goal. On the other hand, Golledge (1999) argued that neither humans nor animals develop complete and precise knowledge of an explored environment. He claimed that these cognitive maps cannot be perfect, otherwise they would be unmanageable.

Hintzman, O'Dell and Arndt (1981) conducted 14 experiments in order to examine the structure of cognitive maps in humans. In these experiments, the participants had to point to some targets while imagining themselves in various orientations. The spatial information was either committed to memory (i.e cognitive maps) or directly presented on each trial in the visual or tactile modality. They calculated the reaction times of the participanrs and those calculations indicated that orientation shifts were achieved through mental rotation in the visual task, but not in the cognitive map or tactile tasks. Further, in the latter two tasks targets were located most quickly when they were adjacent to or opposite the imagined orientation. Several explanations of this finding were tested. Various aspects of the data suggested that cognitive maps are not strictly holistic, but consist of orientation-specific representations.

Besides these psychophysical viewpoints, Lambrinos et al. (2000) described a computational model in which insect navigation was implemented on a mobile robot. Results of this study showed that, although the agent does not have a metric map itself, it was able to extract some metric information from the topological map when it contains some additional information like orientation of the connections.

2.2 Cognitive Map Construction in Virtual Environments

The use of Virtual Environments in psychology provides the ability to produce ecologically valid experiments, where the experimenter has the chance to maintain complete control of the virtual world around the subject (Loomis, Blascovich & Beall, 1999). Human factors issues and general goals of users for visualizing data such as identifying, locating and comparing are used as the cues for representations in these type of experiments (Baker & Wickens, 1992).

Cognitive mapping, the acquisition of environmental knowledge, is one of the psychological topics, which appears to be easily examined in virtual environments because of the advantages that the technology brings. While using Virtual Reality Technology, not only small-scale, ordinary environments, but also large-scale, novel environments can be handled for the manipulations of the topic (Loomis, Blascovich & Beall, 1999). In the first attempts of the studies for this purpose, it was claimed that while immersed in a virtual environment for spatial learning and navigation rehearsal, inhibition of map building can be observed because of rotating frame (Baker & Wickens, 1992). After this claim, number of experiments done in the field and it is found that cognitive map formation is possible in virtual reality environments (Gillner & Mallot, 1998; Yokosawa, Wada & Mitsumatsu, 2005; Melanson, Kelso & Bowman, 2002). In present, there is little disagreement that humans possess the ability to generate a cognitive map. What is typically debated is what is made explicit within the cognitive map and how this spatial information is acquired (Gillner & Mallot, 1998; Stankiewicz & Kalia, 2004; Tversky, 1993).

Since there are number of possibilities for designing virtual environments related research studies, many researchers have started to use the technology. In one of these cognitive mapping studies, Yokosawa, Wada and Mitsumatsu (2005) performed an experimental task in which the participants learned a route by searching in the virtual environment. The participants were given an orientation task on the basis of the cognitive map that they had constructed. The authors investigated how information can be acquired accurately from a cognitive map of the same format or from cognitive maps of different formats in route learning and verification. In the study, two different cognitive map formats were examined, namely *route map* and *survey map*[6]. In route maps, the environment is presented in a viewer-centered frame of reference that reflects the person's navigational experiences, while in survey maps distant places are linked together to form a coherent global overview of the entire environment. The results of the study indicated that the cognitive map was formed as a survey map even if the participants have learned the virtual environment on the basis of a route map.

Another study on this topic was conducted by Gillner and Mallot (1998). They studied the competences of participants related to goal-independent memory of space, or cognitive maps. These competences include seaching locations, finding shortcuts and novel paths, estimating distances between remembered places and drawing sketch maps of the explored virtual maze. The results of the study showed that participants were able to learn the virtual environment from exploration in a virtual environment even with sequences of local, restricted views and movements. Furthermore, there were two additional important findings of the study about cognitive maps. First, the sketch maps, which were drawn by participants, were often locally correct but globally inconsistent and second, connectivity was almost correct but metric properties like angles and lengths were grossly mistaken because of not moving for

---

[6] For further reading see http://www.traclabs.com/~korten/publications/PLAN.pdf

exploring the environment in a sense it occurs in real-world cases. While discussing these results, the authors supported the fact that configurational knowledge is attained when the subject navigates through virtual environments even though participants did not actually move but were interacting with a computer graphics simulation (Gillner & Mallot, 1998).

2.3 Navigation & Path Finding in Virtual Environments

Since virtual environments are useful for the study of spatial cognition, it has also been used as a tool for studying the abilities of subjects for navigating and path finding in explored virtual environments (Darken, 1999; Bowman, Davis, Hodges & Badre, 1999; Stankiewicz et al., 2004; Arthur & Hancock, 2001; Witmer et al., 1996; Richardson, Montello & Hegarty, 1999; Moffat, Zonderman & Resnick, 2001; Waller, 2000).

Stankiewicz, Legge, Mansfield and Schlicht conducted a study that examined ideal spatial navigation (2004). They described three spatial navigation experiments that investigate how limitations of perception, memory, uncertainity and decision strategy affect the desired performance. In the study, they used virtual reality indoor environments that were visually impoverished by limiting the visual information for the human and ideal observer. They designed an ideal navigation model by eliminating the limitations related with human capabilities. The model was assumed to provide optimal behavior for each environment and for each task and it was used for estimating human navigation efficiency by computing the ratio of the number of actions required by the ideal navigator relative to the number of actions taken by the human participants. The results of these three experiments showed that there was a reduction in the participants' efficiencies as the size of the visual layout increased whereas there was no change as the visual information in the layouts decreased. As a last remark, the authors claimed that the reduction in the efficiency for large layouts were due to inefficiencies in the participants' spatial updating strategy rather than the limitations of perception, memory or the decision strategy. Stankiewicz, Legge, Mansfield and Schlicht justify their conclusions with their findings as indicating no difficulty for the participants to access their cognitive maps whereas having difficulty for integrating the set of observations and actions with their cognitive map to generate an accurate list of further states to navigate in the environment.

In another study, Arthur and Hancock (2001) aimed to evaluate how individuals develop representational models to match virtual environments. In the experiment of this study, the authors examined participants' accuracy in reproducing representations of 9 common objects arranged on a flat plane in three different conditions. These three conditions were in a virtual environment, which allowed active exploration, a static virtual environment, which allowed only a passive opportunity for observation, and the static view of a map, which provided only a passive observation from a single viewpoint. Results of the study indicated a linear increase in response latency as the rotation angle[7] increased in both the map and static virtual environment conditions. On the other hand, the virtual navigation condition did not show such an effect for orientation angle[8]. These findings supported the idea that the spatial knowledge acquisition from navigation in virtual environments can be similar to real-world navigation when the viewing condition is unconstrained. Furthermore, since their findings confirms a high usability rating for virtual environments in the task, the authors defended those environments as holding great promise for spatial navigation learning.

Virtual environments were also evaluated for training individuals to navigate in an unknown complex building (Witmer et al., 1996). In this study, three learning conditions were compared. These conditions included training in a virtual environment model, in the actual building and by giving verbal directions and photographs about that building. Route knowledge and building

[7] This angle (degrees) specifies a horizontal orientation relative to the front view. Along with the "height angle", it defines an exact direction. http://composite.about.com/library/glossary/o/bldef-o3732.htm

[8] The relative angle of the warp direction in a fabric to the chosen zero direction shown on the face of the drawing, measured counter-clockwise from the viewpoint of the source. http://composite.about.com/library/glossary/o/bldef-o3732.htm

configuration knowledge were taken as the measurements of the study. Results showed that virtual environment condition produced more route knowledge than verbal rehearsal, but less than exploring in the actual building. Moreover, type of rehearsal, verbal or visual, showed no effect on configuration knowledge. Similar to the conclusions of Arthur and Hancock (2001), the authors of this study suggested that virtual environments, which adequately represent real world complexity, can be effective training media for learning complex routes in buldings, and should be considered whenever the real-world site is unavailable for training.

The nature of the spatial representations of environments acquired from maps, real-world navigation and virtual environments were also assessed by Richardson, Montello and Hegarty (1999). In this study, all the conditions showed similar levels of performance in learning the layout on a single floor. On the other hand, the learners in virtual environment condition were particularly susceptible to disorientation after rotation. Despite this limitation, the authors emphasized the result that the initial simple virtual environment was highly predictive of learning in a real environment and suggested that similar cognitive mechanisms are involved in both real-world and virtual environment training situations.

Individual differences also gained attention while studying Virtual Environments in order to design better systems for the users that have different cognitive abilities (Chen, Czerwinski & Macredie, 2000). Individual differences in spatial learning from computer-simulated environments were also studied by Waller (2000). He found the psychometrically assessed spatial ability and proficiency with the navigational interface as making substantial contributions to individual differences in the ability to acquire spatial information from a virtual environment. The effect of gender was also examined in this study and it was found to influence many virtual environment tasks, primarily through its relationship with interface proficiency and spatial ability. Waller, like previously mentioned authors, also recommended that virtual environments can be useful for training people about real-world spaces since the spatial knowledge of a virtual maze was found to be highly predictive of subsequent performance in a similar real-world maze. He points out that individual differences can account for only a small portion of performance differences and more research is needed to better identify these differences, understand them, and relate them to individual performance.

Age-related deficits in human spatial navigation were also studied by using virtual environment technology (Moffat, Zonderman & Resnick, 2001). In this study, the purpose was to assess age differences in navigational behavior in a virtual environment and to examine the relationship between this navigational measure and other more traditional measures of cognitive aging. Results of this study showed that older participants took longer to solve the trials in the experiments, traversed a longer distance and made significantly more spatial memory errors as compared to younger ones. Furthermore, the performance on the virtual environment navigation task was found to be positively correlated with measures of mental rotation[9] and verbal and visual memory.

2.4 Object Recognition in Virtual Environments

There are also some studies in order to examine the object recognition performance of participants in Virtual Reality Systems. In one of these studies, an experiment was conducted for memory for the orientation of objects by looking at the role of active participation in virtual environments (Wilson, 1999). Surprisingly, the results of this study showed that there is no difference between active and passive participants and active exploration would not allow for better performance than passive observation. In addition, Wilson's study was modified by using more immersive CAVE environment. It was thought

[9] The ability to rotate mental representations of two and three-dimensional objects. For further reading see Shepard, R.N. & Metzler, J. (1971). Mental rotation of three dimensional objects. Science, 171, 701-703.

that this would change the results of the previous experiment but this experiment also yielded no significant indication that active exploration or passive observation changes the level of spatial learning (Melanson, Kelso & Bowman, 2002).

In another study, people with learning disabilities were asked to perform object recognition test of their knowledge of an explored virtual environment (Rose, Brooks & Attree, 2002). There were both active and passive participants and the results of the study indicated no effect of active exploration to enhance their memory of the virtual objects. In addition, virtual training was found to transfer to real task performance with these participants having learning disabilities.

Gamberini (2000), studied object location and object recognition performances of participants in virtual reality environments. He examined the effects of desktop and immersive virtual reality environments on both recall of perceptual characteristics and the location of some objects. Results showed no difference between groups in object location task whereas participants in immersive virtual condition performed less efficiently than the subsequent group in object recognition task.

2.5 Intentional vs. Incidental Learning

In his Inattentional Amnesia hypothesis, Wolfe (1999) states that once attention is removed from an object, no memory trace remains for that object having been attended. After attention is moved away, the visual information about the environment returns to its preattentive state. As a result, Wolfe claims that the desired level of visual learning cannot occur incidentally. In a similar way to Wolfe, Rensink (2000) has presented arguments in his coherence theory, which outlines a visual representation that is limited to one or two currently attended objects. Accordingly, Irwin and Andrews (1996) posited that visual representation consists of the last 3 or 4 items having been attended. They claim that, once the item is no longer being attended and visual short-term memory (VSTM)[10] has reached its full capacity, the object is stored as an abstract, semantic-based representation in long-term memory (LTM). In other words, they defended the idea that visual information is never stored in LTM in this specific case, only the abstract, high-level processed information is encoded.

On the other hand, in another study, no significant difference in object recognition performance was found between the intentional and incidental

---

[10] For further reading see

- Alvarez, G.A., & Cavanagh, P. (2004). The capacity of visual short-term memory is set both by visual information load and by number of objects. *Psychological Science, 15(2),* 106-111.
- Luck, S.J., & Vogel, E.K. (1997). The capacity of visual working memory for features and conjunctions. *Nature, 390,* 279-281.

learning tasks, although there was a tendency for participants to perform better for objects seen in the intentional learning task (Castelhano & Henderson, 2002).

The accuracy of participants for remembering the locations of individual objects was also studied in this manner (Hollingworth, 2005). In this study, the objects were presented in a natural scene. Participants viewed an image of a real-world scene (preview scene), followed by a target object in isolation. Finally, they saw a blank screen with a mouse cursor. Then, the position of the target was estimated by using a mouse. In the tests, three conditions were compared. In the first condition, the target object was present in the scene preview. In the second condition, the target object was not present in the scene preview. Finally, in the third condition, no preview scene was displayed. Results showed that, the localization accuracy in the first condition was reliably higher than that in the second condition, which was reliably higher than localization accuracy in the last condition. Hollingworth, in accordance with these results, proposed that participants can remember both the spatial context of a scene and the specific positions of local objects.

2.6 Summary

In present, there is little disagreement that humans possess the ability to generate a cognitive map, even in virtual environments (Gillner & Mallot, 1998; Yokosawa, Wada & Mitsumatsu, 2005; Melanson, Kelso &

Bowman, 2002). It is supported that configurational knowledge is attained when the subject navigates through virtual environments even though participants did not actually move but were interacting with a computer graphics simulation (Gillner & Mallot, 1998).

Object recognition experiments in virtual environments showed that there is no difference in the performance of the participants according to their active participation (Wilson, 1999; Melanson, Kelso & Bowman, 2002) or the type of virtual display they used (Gamberini, 2000).

There is an ongoing debate for the comparison of intentional and incidental learning. Some researchers claim that the desired level of visual learning cannot occur incidentally (Wolfe, 1999; Rensink, 2000; Irwin & Andrews, 1996) while others support the idea that there are no differences in the performance of incidental and intentional learning tasks (Castelhano & Henderson, 2002; Hollingworth, 2005).

Under the light of these studies, it seems appropriate to combine all the questions in a research to examine the possibility of incidental learning and the role of attention for cognitive map formation and object recognition. For this purpose, following questions will be answered in this study:

- Do the participants incidentally learn the configuration of the virtual environment?

- Do the participants incidentally recognize the objects in the virtual environment?
- Do the participants incidentally learn the locations of the objects in the virtual environment?
- Does the performance of the participants decrease with divided attention?

CHAPTER 3

RESEARCH DESIGN

3.1 Building the Virtual Environment

In this study a Virtual Park was constructed as the Virtual Environment for the experiments to be conducted. The software used for this purpose was Active Worlds, which allows users to create and maintain every detail of their own 3D world, from claiming real estate to building advanced 3D structures and/or visualization scenarios to writing programs that interact with their world. Users who do not need their own world still have the chance to join in on the collaboration by registering as an iUni citizen and logging into one of the existing iUni worlds using the freely available iUni browser (Börner, Wright & Boyles, 2002). It is different from most 3-D systems in that its environments are created entirely online.

Figure 3.1 shows the Active Worlds Browser interface. It provides a "List of worlds and teleports[11]" for easy navigation on the left hand side, a 3-D virtual reality window and a chat window in the middle, and a Web Browser Window on the right hand side (Börner, 2001).

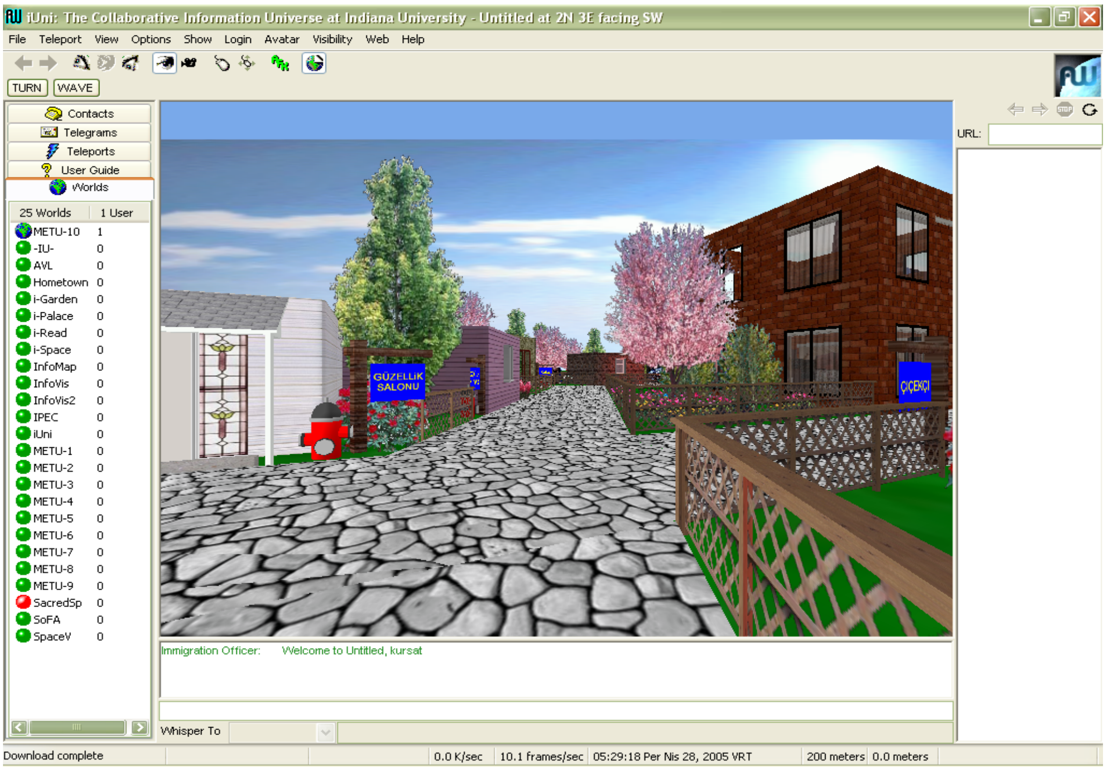


Figure 3.1 Active Worlds Browser interface showing the perspective view of the Virtual Park

3.1.1 iUni – Information Universe

iUni is the collaborative information universe that was created by using Active Worlds Software at Indiana University (Börner, Wright & Boyles, 2002).

Currently, the universe hosts 25 virtual worlds, one of which contains the Virtual Park that was created for this study. The software was used with the permission of Indiana University.

[11] List of other virtual environments that were created by using iUni Software.

3.1.2 Virtual Park

In the virtual environment, which is designed for the purpose of this study, there are 19 buildings, 6 of which can be explored for the objects they contain (See Figure 3.2).

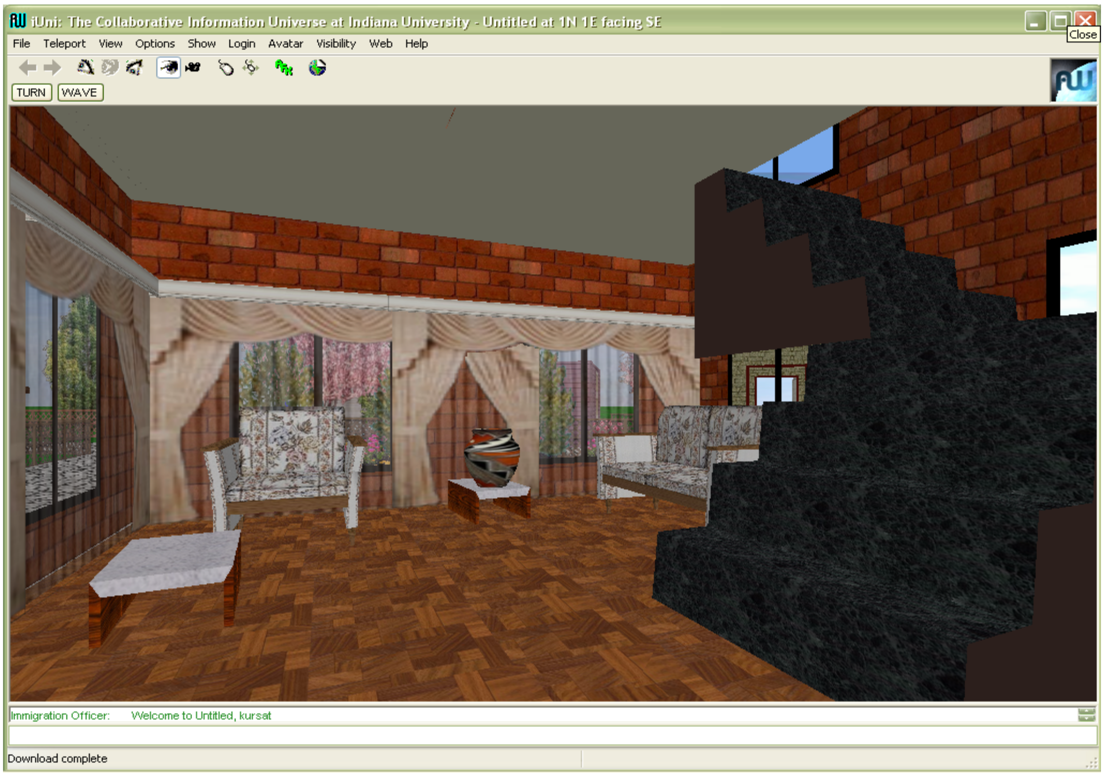


Figure 3.2 : The inner appearance of one of the buildings in the Virtual Park

The other 13 buildings can only be seen from outside. In the open buildings there are more than 100 objects and 9 of those objects were asked in the object recognition test. Furthermore, all of the buildings and the objects were placed as they would be in real world cases. There were not any unusual case that made the participants confused about the organisation of the environment.

The Virtual Park has two gates and the participants were not forced to use a specific one for entrance. The area of the Virtual Park is a square with edges of 60 meters. In order not to confuse the participants, textures of all buildings were selected as being different. Figure 3.3 shows the appearance of Virtual Park from above.

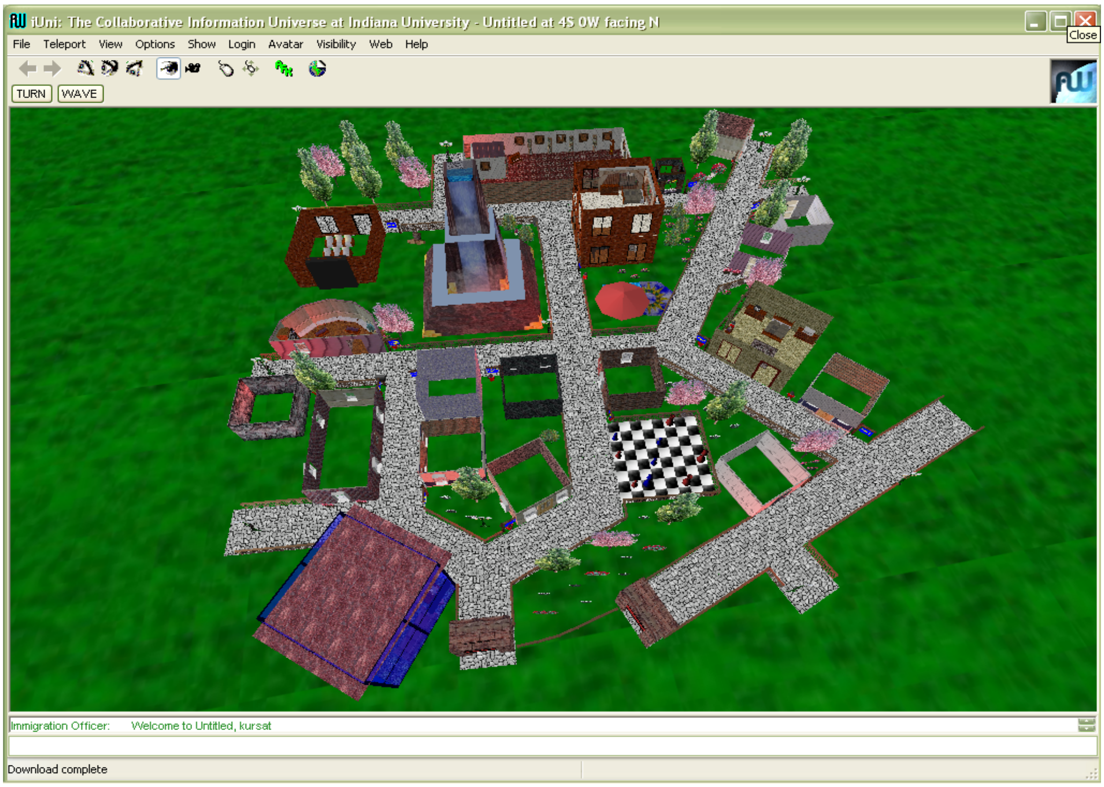


Figure 3.3: Top view of the Virtual Park

3.2 Method

Performance measurement in Virtual Reality Environments has the ability to provide a simultaneous view of the user's actions in the real-world virtual environment interface (Lampton, Bliss & Morris, 2002). In order to collect data for the efficiency of any Virtual Reality application, there are mainly two levels of measures:

what the user accomplished in Virtual Environments

why the performance was successful or not

In this research, the role of attention on constructing cognitive maps and recognizing objects was examined on these two levels; without violating the important properties of measurement such as reliability, validity and sensitivity.

The experiment was done in the between-subjects format; three groups were defined according to participants' focus of attention in the exploration part. Group 1 was defined as attentive, Group 2 was defined as divided-attentive and finally Group 3 was defined as incidental. The participants were randomly allocated to one of these three groups.

All subjects were volunteers and were evaluated individually. The participants in Group 1 and Group 2 had previous knowledge of the requirements of test part of the experiment while they were exploring the environment. Only the participants in Group 3 had no idea about the test requirements. In addition, no participants were required to have used a Virtual Environment previously and none of them had any experience with iUni software. Therefore, performance on a task was not dependent on the familiarity of the virtual environment for the user.

3.2.1 Participants

These were 60 people affiliated with the Middle East Technical University: 43 undergraduate students and 17 graduate students (See Table 3.1). In each three experimental group there were 20 participants and the groups were constructed randomly.

Table 3.1 Descriptive Statistics for the educational status of the participants

	Frequency	Percent
Junior	8	13,3
Senior	35	58,3
MS	1	1,7
PhD	16	26,7
Total	60	100,0

Of the participants, 23 were female. The gender distribution of the groups can be seen in Table 3.2 below.

Table 3.2 Gender Distribution in the Groups

		Frequency
Group1	Female	10
	Male	10
Group2	Female	7
	Male	13
Group3	Female	6
	Male	14

The average age was 23,58 *(sd = 2,612)*. The range was 12 with the minimum age as being 18 (See Figure3.4).

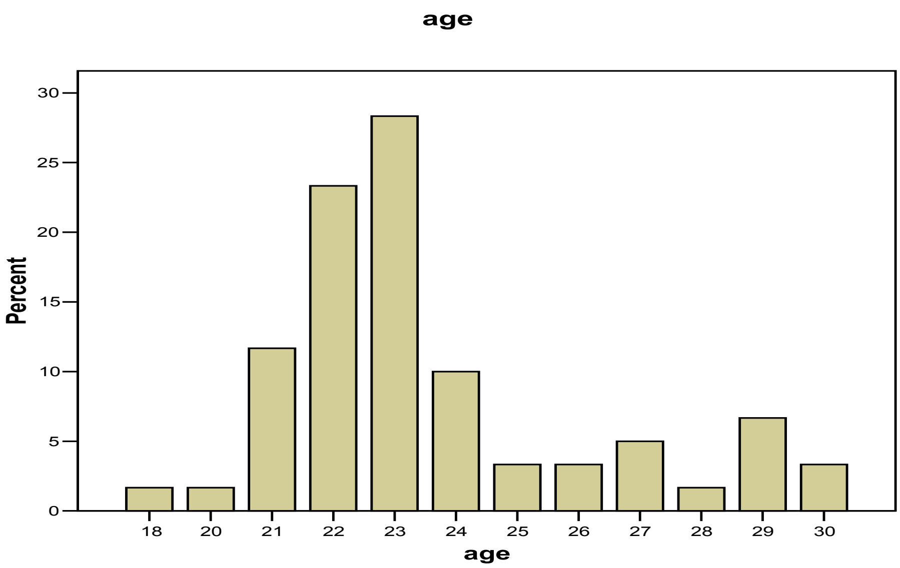


Figure 3.4 Age distribution of the participants

The average CGPA of the participants were 3.075, 3.127 and 3.069 for Group1, Group2 and Group3 respectively. All of the participants were using computers at least for 3 years and most of them were using computers for more than 20 hours a week. Tables 3.3 - 3.8 shows participants' computer experience and their weekly usage of computers in each group.

Table 3.3 Computer experience of the participants in Group1

Group1	Frequency	Percent
3-4 years	2	10,0
4-5 years	6	30,0
> 5 years	12	60,0
Total	20	100,0

Table 3.4 Computer experience of the participants in Group2

Group2	Frequency	Percent
3-4 years	1	5,0
4-5 years	2	10,0
> 5 years	17	85,0
Total	20	100,0

Table 3.5 Computer experience of the participants in Group3

Group3	Frequency	Percent
3-4 years	4	20,0
4-5 years	3	15,0
> 5 years	13	65,0
Total	20	100,0

Table 3.6 Weekly usage of computer for the participants in Group1

Group1	Frequency	Percent
5-10 hours	3	15,0
10-15 hours	2	10,0
15-20 hours	1	5,0
20-25 hours	1	5,0
> 25 hours	13	65,0
Total	20	100,0

Table 3.7 Weekly usage of computer for the participants in Group2

Group2	Frequency	Percent
< 5 hours	1	5,0
5-10 hours	3	15,0
10-15 hours	2	10,0
15-20 hours	1	5,0
20-25 hours	5	25,0
> 25 hours	8	40,0
Total	20	100,0

Table 3.8 Weekly usage of computer for the participants in Group3

Group3	Frequency	Percent
5-10 hours	1	5,0
15-20 hours	3	15,0
20-25 hours	6	30,0
> 25 hours	10	50,0
Total	20	100,0

Almost all of the participants were used to play computer games (See Table 3.9-3.11).

Table 3.9 Frequency of computer-game playing for the participants in Group1

Group1	Frequency	Percent
Never	2	10,0
Rarely	5	25,0
Sometimes	7	35,0
Frequently	6	30,0
Total	20	100,0

Table 3.10 Frequency of computer-game playing for the participants in Group2

Group2	Frequency	Percent
Never	2	10,0
Rarely	7	35,0
Sometimes	7	35,0
Frequently	4	20,0
Total	20	100,0

Table 3.11 Frequency of computer-game playing for the participants in Group3

Group3	Frequency	Percent
Never	5	25,0
Rarely	9	45,0
Sometimes	4	20,0
Frequently	2	10,0
Total	20	100,0

3.2.2 Apparatus

The virtual environment was created on a Intel Pentium IV CPU 2.40GHz Desktop Computer with Internet connection. The objects were manipulated using the iUni Software, developed at Indiana University (Börner, Wright, Boyles, 2002).

The Sony® VPL-ES2 mobile projector was used in order to make the participants to explore the virtual park in front of a large projection screen rather than a 17" desktop monitor. This is because, when the 3D graphical virtual world is displayed on a standard computer screen, the user does not have true 3D depth perception and the sense of presence is low.

3.2.3 Procedure

In the experiments of this study, participants explored the virtual park under one of three attentional states. Then, all participants were tested according to their ability to construct a cognitive map of that environment and also their ability to recognize the objects and their locations that were seen in the exploration (see Appendix A for the instructions that were given to the participants).

There were three experimental groups with three attentional states, each of which includes 20 participants. In the first attentional state (i.e attentive group), the participants (Group1) explored the environment in an attentive way as being informed about the required performance after exploration. They were instructed to concentrate on the objects, their locations and the map of the environment. In the second one (i.e divided-attentive group), the participants (Group2) were given an additional task to make them divide their attention into these two tasks. They were instructed not only to concantrate on the objects, their locations and the map of the environment but also to count the fireplugs in the Virtual Park. Since both tasks require attention, subjects in this group had distributed attentional source for completing the required tasks. Finally, in the third state (i.e incidental group), the participants (Group3) were only instructed to do a different task than the actual one in order to test their level of learning that occured incidentally. They were just told that they are responsible for counting the fireplugs located in the virtual park (See Figure 3.5).

The fireplugs were located both inside and outside of the buildings in order to be sure that the participants would also see the objects in the buildings as well as the roads of the Virtual Park. Since they were just told that the important thing is the number of the fireplugs, they did not pay attention to the locations of buildings and objects.

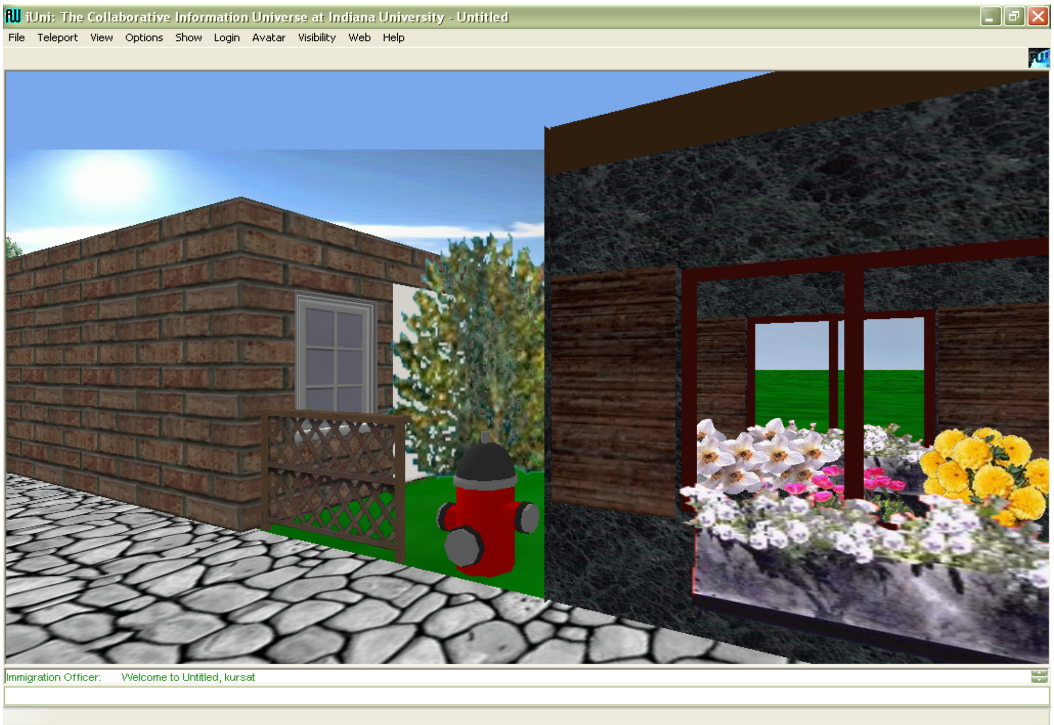


Figure 3.5: The fireplug located in the Virtual Park

Before starting the exploration, all subjects were given time to explore a similar environment so that they would be familiar with the controls for the computer program. This exploration was not a part of the recorded time-spent, but only a way to give practice time with the controls and nothing more. The subjects were then located at the entrance of the virtual park and instructed according to their group in the experiment.

In the end nodes of the virtual park, there are nine street lamps, which have numbers (between 1 to 9) on them. During the experiments, a paper containing the pictures of these 9 numbers was in front of the researcher and she placed a check sign near the pictures as the participants faced those objects while they were exploring the virtual environment. By this way only, the researcher would be sure that all parts of the virtual environment were seen by the participants since those 9 numbers would be seen only if a participant explores every part of the environment.

After active exploration, participants were asked to answer the questions that examined their memory for the locations of objects in the virtual park. They were required to write the names of the buildings in a given map that represents the park's appearance from above.

They were also be examined according to their recognition of objects. For this purpose, they were given 18 cards, 9 of which shows the objects that are actually placed in the buildings and 9 of them shows unseen distractors. Then, they were asked to examine each picture and indicate if they saw the object in the environment. If an object is recognized by the subject, he/she was asked to indicate in which building he/she saw it.

3.2.4 Measurements

The first measurement in the experiment was the time that each participant spent exploring the environment. This value was recorded for each of the participants in all experimental groups. The extra time, which was given for exploring another environment in order to make the participants to be familiar with the controls for the computer program, was not included in this measurement.

The next measurement tested the participants' memory for the locations of buildings. At the end of the experiment, each participant was given a map of the environment and asked to indicate the locations of all buildings they remembered on the map. Points were given, to a maximum of 38, as follows: 2 points for each correct building in the correct location and 1 point for each correct building in an incorrect location.

Another measurement was the participants' recognition of objects in the environment. Participants indicated their recognition of the objects shown in flash cards and points were given both for the actual and distracter objects separately. Points for the actual objects were given, to a maximum of 9, as giving 1 point for each correctly recognized object (i.e. hit) and 0 point for misses. Furthermore, 1 point was given for each distracter object correctly identified as unseen (i.e. correct rejection) and 0 point was given for false alarms.

The final measurement was the participants’ memory for the location of the objects in the environment. These objects were the same with those used in the recognition test. Participants indicated their memory for the location of an object if they report that object as familiar. Points for the actual objects were given, to a maximum of 9, as giving 1 point for each correctly identified location and 0 point for false responses.

The collected data was also examined according to the participants' computer experience, computer usage, computer game experience and gender. The related information was collected from the participant information form (Appendix A) that was filled by each participant before the experiment.

CHAPTER 4

RESULTS & DISCUSSION

4.1 Results

Analysis of results was done by entering the data into SPSS. Correlations, Regression, Analysis of Variance (ANOVA) and general statistics were run on all data. The results from SPSS is reviewed in this subsection and conclusions are drawn accordingly. The result tables obtained from SPSS can be found in Appendix B.

There is a highly significant difference between the three groups according to their performance on constructing a cognitive map for the environment *($F(2,57)=108.873$, $p < .05$).* Here, the measure is the scores of the participants in locating the names of the buildings in the given map of the environment. Our predictor (i.e. focus of attention) is particularly good at predicting the cognitive map performance *(Adjusted R Squared = .785)*. In order to see where the differences lie, a post hoc test, which is in our case the

Scheffe[12] test, was done. In this multiple comparisons the mean difference between *Group1* and *Group2* was 10.85, between *Group1* and *Group 3* was 18.80 and between *Group2* and *Group3* was 7.95 while having all our p-values as highly significant *($p < .05$).* Since all three groups differ significantly, there are three homogeneous subsets obtained from the Scheffe test. The mean performance scores were 26.2, 15.35, 7.4 for *Group1*, *Group2* and *Group3* respectively (see Table 4.1).

Table 4.1 Mean cognitive map scores for groups (out of 38)

Group	Mean	N	Std. Deviation
Group1	26,20	20	4,884
Group2	15,35	20	4,356
Group3	7,40	20	2,501
Total	16,32	60	8,728

When we take "time" (i.e the elapsed time during the exploration part of the experiment), "computer experience" (i.e how long the participant has been using a computer) and "weekly computer usage" (i.e how many hours in a week the participant uses a computer) into consideration as covariates; results of ANCOVA show that only time has a significant effect on cognitive map performance *($F(1,54)=30{,}079$, $p<.05$)* while focus of attention still has an significant effect independently *($F(2,54)=82{,}427, p<.05$).* The performance scores

[12] This post hoc test can be used to determine the significant differences between group means in an analysis of variance setting. (for a detailed discussion of different post hoc tests, see Winer, B.J., Brown, D. R., Michels, K.M. (1991). Statistical Principles in Experimental Design. *McGraw-Hill, New York, 3rd edition).*

of the participants on cognitive mapping task became higher as the elapsed time increased.

There is again a significant difference between the three groups according to their object recognition performance *($F(2,57)=13.525$, $p < .05$).* On the other hand, our predictor (i.e. focus of attention) shows a poor fit for predicting this data *(Adjusted R Squared = .298).* In the multiple comparisons the mean difference between *Group1* and *Group2* was 0.5, between *Group1* and *Group 3* was 2.65 and between *Group2* and *Group3* was 2.15 while having only the p-value for the last two couples are significant *($p< .05$).* Furthermore, the mean performance scores were 5.65, 5.15 and 3 for *Group1*, *Group2* and *Group3* respectively (See Table 4.2). Moreover, neither of the covariates (i.e time, computer experience, weekly computer usage) found to have an effect on object recognition scores (see Appendix B for the result tables obtained from SPSS).

Table 4.2 Mean object recognition scores for groups (out of 9)

Group	Mean	N	Std. Deviation
Group1	5,65	20	1,927
Group2	5,15	20	1,565
Group3	3,00	20	1,622
Total	4,60	60	2,044

When we look at the participants' performance scores for the memory for the locations of the objects, there is again a significant difference between the three groups according to their object recognition performance *($F(2,57)=13.975$, $p< .05$).* In addition, our predictor (i.e. focus of attention) shows a moderate fit for predicting this data *(Adjusted R Squared = .305).* In the multiple comparisons the mean difference between *Group1* and *Group2* was 0.45, between *Group1* and *Group 3* was 2.85 and between *Group2* and *Group3* was 2.40 while having only the p-value for the last two couples are significant *($p < .05$).* Furthermore, the mean performance scores were 4.20 for *Group1*, 3.75 for *Group2* and 1.35 for *Group3* (See Table 4.3). Moreover, neither of the covariates (i.e time, computer experience, weekly computer usage) found to have an effect on object location memory scores (see Appendix B for the result tables obtained from SPSS).

Table 4.3 Mean object location memory scores for groups (out of 9)

Group	Mean	N	Std. Deviation
Group1	4,20	20	1,989
Group2	3,75	20	1,888
Group3	1,35	20	1,599
Total	3,10	60	2,199

While there are significant differences between three experimental groups for their performance for cognitive map formation, object recognition and their memory for the locations of objects, no significant difference was obtained for rejecting the distracter objects in the object recognition test *($F(2,57) = .734$, $p = .484$).* The mean performance scores was 7.5 for *Group1*, 7.25 for *Group2* and 7.7 for *Group3* (See Table 4.4). Furthermore, again neither of the covariates (i.e time, computer experience, weekly computer usage) found to have an effect on rejecting the distracter objects (see Appendix B for the result tables obtained from SPSS).

Table 4.4 Mean performance scores for distracter objects according to groups (out of 9)

Group	Mean	N	Std. Deviation
Group1	7,50	20	1,147
Group2	7,25	20	1,251
Group3	7,70	20	1,129
Total	7,48	60	1,172

In order to see whether playing computer games has an effect on the participants' performance for constructing a cognitive map of the environment, ANOVA was applied on four groups having different levels of computer game experience (See Table 4.5). Results showed an increasing trend for the cognitive map performance scores of the participants as the familiarity with computer games increases but the difference was not significant between the participants having different levels of computer game experience *($F(3,56)=1.283$, $p=.289$)*. There may be an effect here, which cannot be shown as significant because of the low statistical power. This may be due to the insufficient number of participants and more participants may provide us with a significant difference for this test. The same trend was obtained for the object recognition scores but because of the same reason (i.e. insufficient number of participants) the difference was not significant between the participants having different levels of computer game experience *($F(3,56)=2.168$, $p= .102$)*. On the other hand, neither a trend nor a significant difference was found between the participants having different levels of computer game experience in either their memory scores for the locations of the objects *(F(3,56)=1.680, p=.182)* or their performance for rejecting the distracter objects in the experiment *(F(3,56)=1.582, p= .204).*

Table 4.5 Mean cognitive map scores for participants' computer game experience (out of 38)

Game playing	Mean	N	Std. Deviation
never	14,00	9	8,588
rarely	14,95	21	9,168
sometimes	16,33	18	6,713
frequently	20,42	12	10,308
Total	16,32	60	8,728

In addition, t-test was used to examine the effect of gender on participants' performance and no significant difference was found between males and females in their cognitive map performance *(t(58)= 0.933, p = .353),* object recognition performance *(t(58)= -.620, p = .586),* their memory scores for the locations of the objects *(t(58)= .806, p = .523)* and distracter object rejection scores *(t(58)= 0.199, p = .244).*

Table 4.612 Mean performance scores according to the gender of the participants

	gender	N	Mean	Std. Deviation
Cognitive map score	female	23	17,65	7,547
	male	37	15,49	9,392
Object recognition score	female	23	7,78	3,777
	male	37	7,65	4,224
Object location score	female	23	3,39	2,017
	male	37	2,92	2,314
Distracter object score	female	23	15,04	2,688
	male	37	14,92	2,139

4.2 Discussion

The results of the study showed that configurational knowledge can be attained in desktop virtual environments. Participants seemed to be able to form a cognitive map of the virtual environment in order to answer the questions about its configuration. This result is compatible with previous studies (Gillner & Mallot, 1998; Yokosawa, Wada & Mitsumatsu, 2005; Melanson, Kelso & Bowman, 2002).

Another finding of this study is that attention has a significant role on forming cognitive maps since a secondary task caused a decrease in the performance of participants. In addition, it can be claimed with these results that, the incidental formation of a cognitive map is not possible since the performance is significantly poor when compared with the chance level[13]. Furthermore, this case is also true for object recognition task. The performance in this task was below the chance level[14] for inattentive participants and it did not occur incidentally. These findings contradict the results of Castelhano and Henderson (2002) in their study on the memorization of real scene photographs. Their discussion supported the idea that there is no significant difference in object recognition performance between the intentional and incidental learning tasks, while a significant difference was found in this study. On the other hand,

[13] The cognitive map formation score has a chance level of 19 while having the maximum value as 38.
[14] The object recognition score has a chance level of 4.5 while having the maximum value as 9.

their finding, which shows a tendency for participants to perform better in the intentional learning task, is supported with the results of this preliminary work.

While Waller (2000) stated that gender influences many virtual environment tasks, primarily through its relationship with interface proficiency and spatial ability, no significant difference was found between males and females in their cognitive map performance, object recognition performance, memory scores for the locations of the objects and distracter object rejection scores in this study. Furthermore, as an additional and novel finding to the related works, computer game playing, weekly computer usage and computer experience were found have no influence on either task performance in this study. On the other hand, this result is not sufficient to make strong statements because of the low statistical power. Same case should be examined with a large number of participants in order to prove the hypothesis.

As the last finding, the elapsed time for exploration in the virtual environment was found to have a significant effect on cognitive map performance while focus of attention still has a significant effect independently. In contrast, no effect of time was found for object recognition, memory for the locations of the objects and distracter rejection performances. Although similar procedures were fallowed in this study and the study of Melanson et al. (2002), having no effect of time for object recognition contradicts the findings of the other study, since they found that a correlation exists between time spent exploring the environment and the performance in object recognition task.

4.3 Conclusion

If we summarize the correctness of the hypotheses of this study, we can say that all of them was supported with the results of this study. Test scores for the Group1 was the highest for all types of the performances. The performance of the participants in Group2 were lower than that of Group1 and higher than that of Group3. This shows us that attention is an important factor for the required performances in this study. Furthermore, test scores of Group3 were below the chance level for their cognitive map performance, object recognition performance and memory scores for the locations of the objects. This supports the idea that incidental learning did not occur for these tasks in desktop virtual reality environments.

4.4. Future Work

Performance measurement in Virtual Reality Environments has the ability to provide a simultaneous view of the user's actions in the real-world virtual environment interface (Lampton, Bliss & Morris, 2002). In order to collect data for the efficiency of any Virtual Reality application, there are mainly two levels of measures:

- what the user accomplished in Virtual Environments
- why the performance was successful or not

In a future research, the role of attention for cognitive map formation, distance estimation, memory for the locations of the objects and object recognition can be examined on these two levels; without violating the important properties of measurement such as reliability, validity and sensitivity.

Experimentation in psychology entails a tradeoff between experimental control and ecological validity. Virtual Displays afford less of a tradeoff than do traditional approaches to psychological experimentation (see Figure 4.1).

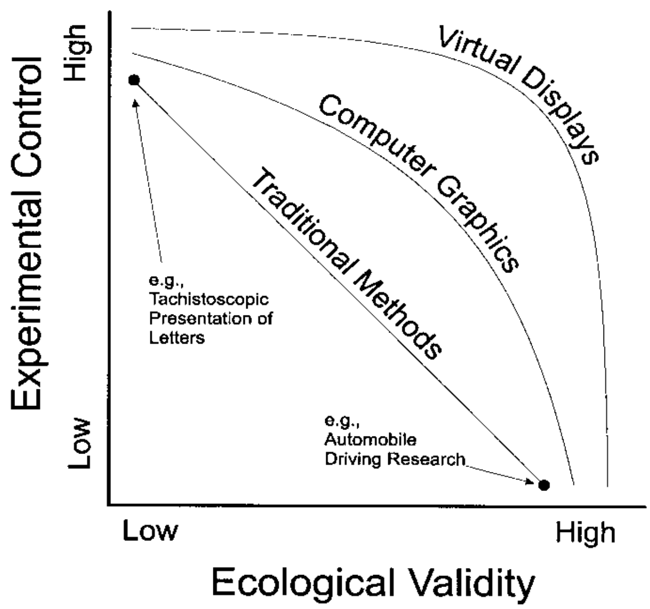


Figure 4.2 Tradeoff between experimental control and ecological validity (Loomis, Blascovich, Beall, 1999, p.558)

Furthermore, especially immersive virtual displays provide us with ecologically valid experiments, where the experimenter has the chance to maintain complete control of the virtual world around the subject (Loomis, Blascovich, Beall, 1999). For this reason, in a future work the truth values of the hypotheses of this study can be examined and the differences between the virtual and the real world can be studied by modeling a real scene by using Immersive Virtual Reality Environments.

References

Arthur, H. J., Hancock, P. A. (2001). Navigation Training in Virtual Environments. *International Journal Of Cognitive Ergonomics, 2001, 5(4), 387–400*

Baker, M., Wickens, C. (1992). Human Factors in Virtual Environments for the Visual Analysis of Scientific Data. *Deliverable to Battelle/Pacific Northwest Laboratory, Richland, Washington. Contract No. DOE BATT 207091-AU2.*

Börner, K. (2001) Using Active Worlds Technology to build an iUniverse of 3-D collaborative learning environments. *IEEE Learning Technology newsletter*.

Börner, K., Wright, E., Boyles, M. (2002). iUniverse: A Collaborative Information Universe for IU. *Abstract submission for I-Light Conference, University Place Conference Center, Indianapolis, IN, December 4th, 2002.*

Bowman, D. A., Davis, E. T., Hodges, L. F., Badre, A. N. (1999). Maintaining Spatial Orientation during Travel in an Immersive Virtual Environment. *Presence, Vol. 8, No. 6, 618–631*

Castelhano, M. S., Henderson, J. M. (2002). Detailed Visual Memory for Objects in Scenes following Intentional and Incidental Learning Tasks. *Michigan State University Eyelab Technical Report, 3, 1-15.*

Chen, C., Czerwinski, M., Macredie, R. (2000) Individual differences in virtual environments – introduction and overview. *Journal of the American Society for Information Science, 51(6), 499-507.*

Darken, R.P. (1996). Wayfinding in Large-Scale Virtual Worlds. The George Washington University, Department of Electrical Engineering and Computer Science; Doctoral dissertation.

Gamberini, L. (2000). Virtual Reality as a New Research Tool for the Study of Human Memory. *Cyberpsychology & Behavior Volume 3, Number 3.Mary Ann Liebert, Inc.*

Gibson, J.J.(1997). Direct perception and ecological optics. In I. E. Gordon, Theories of visual perception, *2nd ed. Chichester, England: John Wiley & Sons. Chapter 7.*

Gillner, S., Mallot, H. (1998). Navigation and Acquisiton of Spatial Knowledge in a Virtual Maze. *Journal of Cognitive Neuroscience, 10 (4), 445 - 464.*

Golledge, R. G. (1999). Precis of "Wayfinding behavior: Cognitive mapping and other spatial processes." PSYCOLOQUY 10(036) http://www.cogsci.soton.ac.uk/cgi/psyc/newpsy?10.036

Hintzman, D. L., O'Dell, C. S., Arndt, D. R., (1981). Orientation in cognitive maps. *Cognitive Psychology, 13, 149-206.*

Hollingworth, A. (in press). Memory for object position in natural scenes. *Visual Cognition: Special Issue on Scene Perception.*

Irwin, D. E., Andrews, R. V. (1996). Integration and accumulation of information across saccadic eye movements. *In T. Inui & J. L. McClelland (Eds.), Attention and Performance XVI: Information Integration in Perception and Communication (pp. 125–155). Cambridge, MA: MIT Press.*

Lambrinos, D., Moller, R., Labhart, T., Pfeifer, R., Wehner, R. (2000). A mobile robot employing insect strategies for navigation. *Robotics and Autonomous Systems, special issue on Biomimetic Robots*, (30) 39–64.

Lampton, D. R., Bliss, J. P., & Morris, C. S. (2002). Human performance measurement in virtual environments. In K. M. Stanney (Ed.), Handbook of Virtual Environments: Design, Implementation, and Applications *(701–720). New Jersey: Lawrence Erlbaum.*

Longman Dictionary of contemporary English (1995). New edition. Harlow: Longman.

Loomis, J., Blascovich, J., Beall, A. (1999). Immersive virtual environment Technology as a basic research tool in psychology. *Behavior Research Methods, Instruments, & Computers* , 31 (4), 557 - 564.

Marr, D. (1982). Vision: A computational investigation into the human representation and processing of visual information. *San Francisco: Freeman. Ch.1*

Melanson, B., Kelso, J., Bowman, D. (2002) Effects of Active Exploration and Passive Observation on Spatial Learning in a CAVE. *Technical Report TR-02-15, Computer Science, Virginia Tech.*

Moffat, S.D., Zonderman, A.B. & Resnick, S.M. (2001). Effects of age on spatial learning in a virtual reality navigation task. *Neurobiology of Aging 22: 787-796.*

Neisser, U. (1976). Cognition and Reality. Principles and Implications of Cognitive Psychology. *Freeman: San Francisco, Fig. 2 and Chs. 2 and 4.*

Rensink, R. A. (2000). The dynamic representation of scenes. *Visual Cognition*, *7*, 17-42.

Richardson, A. E., Montello, D. and Hegarty, M. (1999). Spatial knowledge acquisition from maps, and from navigation in real and virtual environments. *Memory & Cognition*, *27*, 741-750.

Rose, F. D., Brooks, B. M., Atree, E. A. (2002). An exploratory investigation into the usability and usefulness of training people with learning disabilities in a virtual environment. *Disability And Rehabilitation, Vol. 24, No. 11-12, 627 – 633.*

Stankiewicz, B.J., Kalia, A. (2004). Acquisition and Retention of Structural versus Object Landmark Knowledge When Navigating through a Large-Scale Space. *Journal of Experimental Psychology: Human Perception & Performance. Under Review.*

Stankiewicz, B.J., Legge, G.E., Mansfield, J.S. & Schlicht, E.J. (2004). Lost in Virtual Space: Human and Ideal Wayfinding Behavior. *Journal of Experimental Psychology: Human Perception & Performance. Under Review.*

Sutcliffe, A. (2003). Multimedia and Virtual Reality: designing multisensory user interfaces. *(1-65). New Jersey: Lawrence Erlbaum.*

Tolman, E. C. (1948). Cognitive Maps in Rats and Men. *The Psychological Review, 55(4),* 189-208.

Treisman, A. M., Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology, 12, 97-136.*

Tversky, B. (1993). Cognitive Maps, Cognitive Collages and Spatial Mental Models. *In Frank, A. U. and Campari, I. (Eds.) Spatial Information Theory: A Theoretical Basis for GIS, Proceedings COSIT'93. Lecture Notes in Computer Science, 716, pp. 14-24. Berlin: Springer*.

Vince, J. (1999). Essential virtual reality fast: how to understand the techniques and potential of virtual reality. *(27-91). Great Britain: Springer.*

Waller, D. (2000). Individual differences in spatial learning from computer-simulated environments. *Journal of Experimental Psychology: Applied, 8,* 307 – 321.

Wilson, P. (1999). Active Exploration of a Virtual Environment Does Not Promote Orientation or Memory for Objects. *Environment & Behavior , 31 (6), 752 - 764.*

Witmer, B. G., Bailey, J. H., Knerr, B. W., Parsons, K. C. (1996). Virtual spaces and real world places: transfer of route knowledge. *International Journal of Human-Computer Studies Volume 45, Issue 4, 413-428*

Wolfe, J. M. (1999). Inattetnional Amnesia. In V. Colheart (Ed.), *Fleeting Memories* (71-94).

Yokosawa, K.,Wada, E., Mitsumatsu, H. (2005). Coding and Transformation of Cognitive Maps in a Virtual Environment. *Electronics and Communications in Japan, Part 3, Vol. 88, No. 4, Translated from Denshi Joho Tsushin Gakkai Ronbunshi, Vol. J87-A, No. 1, January 2004, pp. 13–19*

APPENDIX A

Test Forms of the Experiment

1. Participant Information Form

Sayın katılımcı,

Bu deney Orta Doğu Teknik Üniversitesi Bilişsel Bilimler Bölümü'nde yürütmekte olduğum tez çalışması kapsamında, sanal gerçeklik ortamlarında görsel algı ve bilişsel işlevleri incelemeye yönelik olarak hazırlanmıştır ve yaklaşık olarak 20 dakika sürmektedir.

Deneye başlamadan önce ekte bulunan formdaki soruları cevaplamanız beklenmektedir. Bu sorulara vereceğiniz cevaplar yanlızca bu araştırma için kullanılacak ve bilgileriniz gizli tutulacaktır. Bu nedenle lütfen her soru için verilmiş olan cevap şıklarından kendinize uygun olan seçeneği işaretleyiniz.

Katkılarınız için teşekkür ederim.

Hacer ÜKE
Orta Doğu Teknik Üniversitesi
Enformatik Enstitüsü

Yaşınız:

Cinsiyetiniz: ☐ Bayan ☐ Erkek

Bölümünüz:

Kaçıncı sınıftasınız?

☐1 ☐2 ☐3 ☐4 ☐Ms ☐PhD

Not ortalamanız:

Ne kadar zamandır bilgisayar kullanıyorsunuz?

☐ 1 yıldan az
☐ 1-2 yıl
☐ 2-3 yıl
☐ 3-4 yıl
☐ 4-5 yıl
☐ 5 yıldan fazla

Haftada kaç saat bilgisayar kullanıyorsunuz?

☐ 5 saatten az
☐ 5-10 saat
☐ 10-15 saat
☐ 15-20 saat
☐ 20-25 saat
☐ 25 saatten fazla

Bilgisayar oyunları oynar mısınız?

☐ Evet ☐ Hayır

Herhangi bir görme probleminiz var mı, varsa nedir?

☐ Evet ________________________ ☐ Hayır

2. Explanation Form for Group1

Deney süresince sizden bilgisayar ortamında gerçekleştilmiş olan sanal parkı incelemeniz ve sonrasında bu sanal parkı zihninizde canlandırmanız beklenmektedir. Park içerisinde bazı binaların içi gezilebilmekte bazılarının ise sadece dış yapısı görülmektedir. Sizden incelemelerinizi hem sanal parkın caddelerinde hem de içi gezilebilmekte olan binaların içinde yapmanız beklenmektedir. Yapacağınız inceleme sırasında dikkat etmeniz gereken bilgi binaların isimleri, içi gezilebilen binalardaki objeler ve binaların parktaki konumları olmalıdır.

Programa uyum sağlamanız açısından aynı ortamda geliştirilmiş olan diğer bir sanal parkta kısa bir süre için alıştırma yapmanıza izin verilecektir. Programın kontrolleri bilgisayarın klavyesi üzerinde bulunan dört ok yardımıyla, ileri / geri / sağ yöne / sol yöne gidiş şeklinde, gerçekleştirilecektir.

Sanal Park'ın tüm alanlarını gördüğünüz size sözlü olarak belirtildikten sonra, kendinizi deney sonrasında sorulacak olan soruları cevaplamaya hazır hissettiğiniz zaman deneyi sonlandırabilirsiniz.

Yapılacak olan işlemler kısaca aşağıdaki maddeler şeklinde özetlenebilir:

- Alıştırma amaçlı olarak kısa süreliğine diğer bir sanal ortamı incelemek
- Sanal Park içerisindeki caddeleri gezip binaların konumunu incelemek
- İçi gezilebilen binaları gezip içindeki objeleri gözlemlemek

3. Explanation Form for Group2

Deney süresince sizden bilgisayar ortamında gerçekleştilmiş olan sanal parkı incelemeniz ve sonrasında bu sanal parkı zihninizde canlandırmanız beklenmektedir. Park içerisinde bazı binaların içi gezilebilmekte bazılarının ise sadece dış yapısı görülmektedir. Sizden incelemelerinizi hem sanal parkın caddelerinde hem de içi gezilebilmekte olan binaların içinde yapmanız beklenmektedir. Yapacağınız inceleme sırasında dikkat etmeniz gereken bilgi <u>binaların isimleri, içi gezilebilen binalardaki objeler ve binaların parktaki konumları</u> olmalıdır. Bu inceleme sonrasında sizden istenecek olan ikinci bilgi ise sanal parkta bulunan <u>yangın musluklarının sayısı</u> olacaktır. Bu sayının doğruluğu deneyin başarısı açısından önem taşımaktadır. Olası herhangi bir karışıklığın engellenmesi açısından ekte sayılacak olan yangın musluğunun resmi konulmuştur.

Programa uyum sağlamanız açısından aynı ortamda geliştirilmiş olan diğer bir sanal parkta kısa bir süre için alıştırma yapmanıza izin verilecektir. Programın kontrolleri bilgisayarın klavyesi üzerinde bulunan dört ok yardımıyla, ileri / geri / sağ yöne / sol yöne gidiş şeklinde, gerçekleştirilecektir.

Sanal Park'ın tüm alanlarını gördüğünüz size sözlü olarak belirtildikten sonra, kendinizi deney sonrasında sorulacak olan soruları cevaplamaya hazır hissettiğiniz zaman deneyi sonlandırabilirsiniz.

Yapılacak olan işlemler kısaca aşağıdaki maddeler şeklinde özetlenebilir:

- Alıştırma amaçlı olarak kısa süreliğine diğer bir sanal ortamı incelemek
- Sanal Park içerisindeki caddeleri gezip binaların konumunu incelemek
- İçi gezilebilen binaları gezip içindeki objeleri gözlemlemek
- Sanal Park içerisinde bulunan yangın musluklarını saymak

4. Explanation Form for Group3

Deney süresince sizden bilgisayar ortamında gerçekleştilmiş olan sanal parkı incelemeniz beklenmektedir. Bu inceleme sırasında dikkat etmeniz gereken bilgi sanal parkta bulunan <u>yangın musluklarının sayısı</u> olacaktır. Bu sayının doğruluğu deneyin başarısı açısından önem taşımaktadır. Olası herhangi bir karışıklığın engellenmesi açısından ekte sayılacak olan yangın musluğunun resmi konulmuştur.

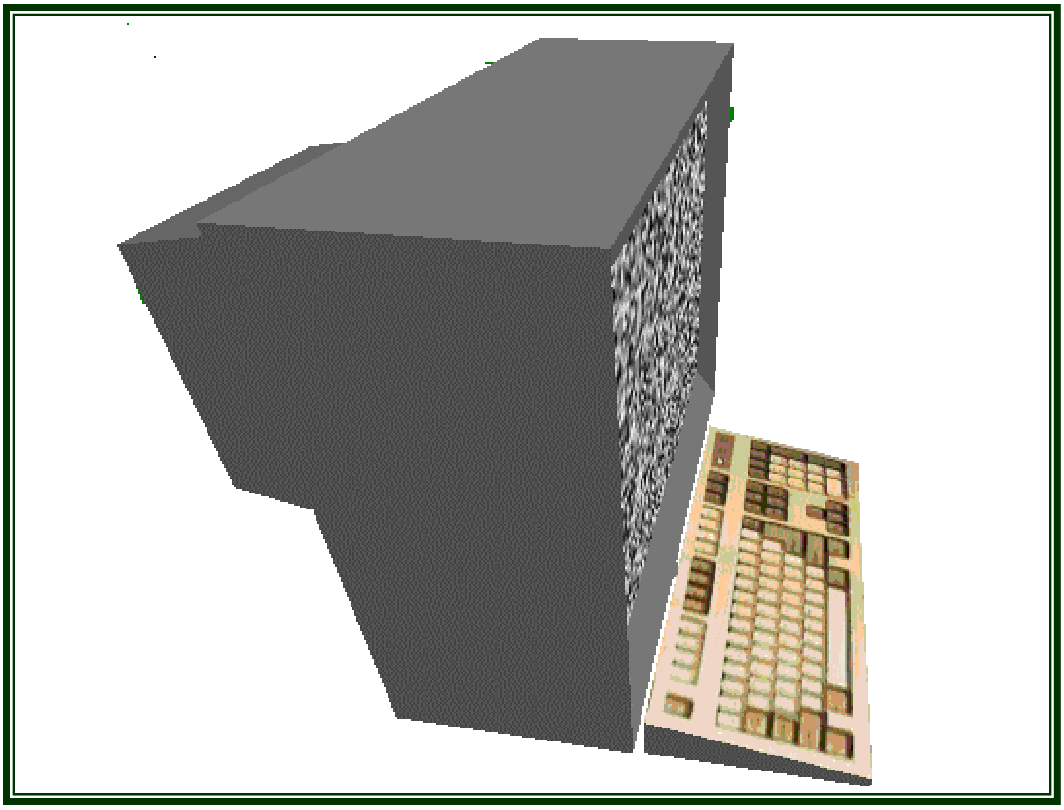
Programa uyum sağlamanız açısından aynı ortamda geliştirilmiş olan diğer bir sanal parkta kısa bir süre için alıştırma yapmanıza izin verilecektir. Programın kontrolleri bilgisayarın klavyesi üzerinde bulunan dört ok yardımıyla, ileri / geri / sağ yöne / sol yöne gidiş şeklinde, gerçekleştirilecektir.

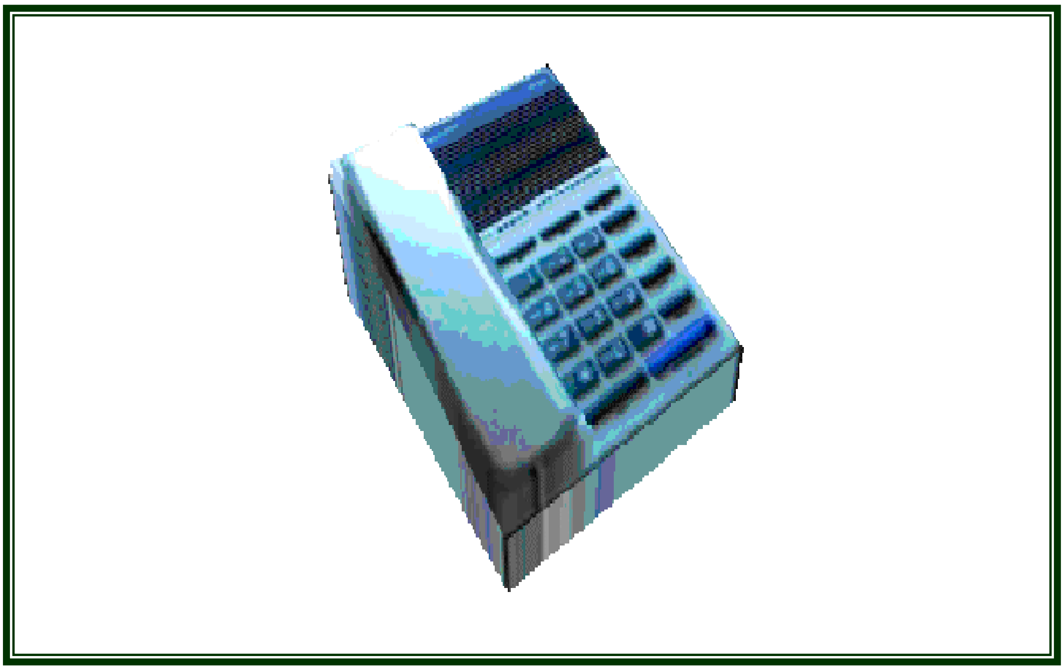
Sanal Park'ın tüm alanlarını gördüğünüz size sözlü olarak belirtildikten sonra, kendinizi deney sonrasında sorulacak olan soruları cevaplamaya hazır hissettiğiniz zaman deneyi sonlandırabilirsiniz.

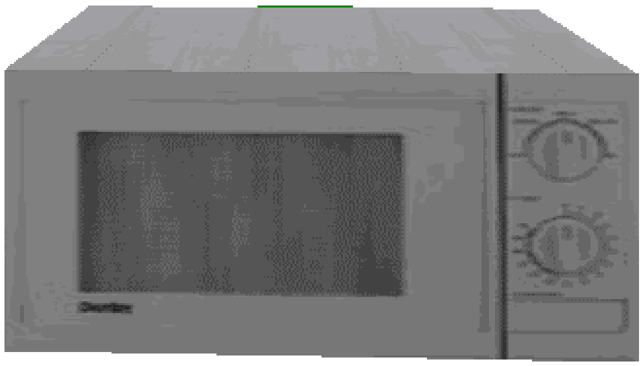
Yapılacak olan işlemler kısaca aşağıdaki maddeler şeklinde özetlenebilir:

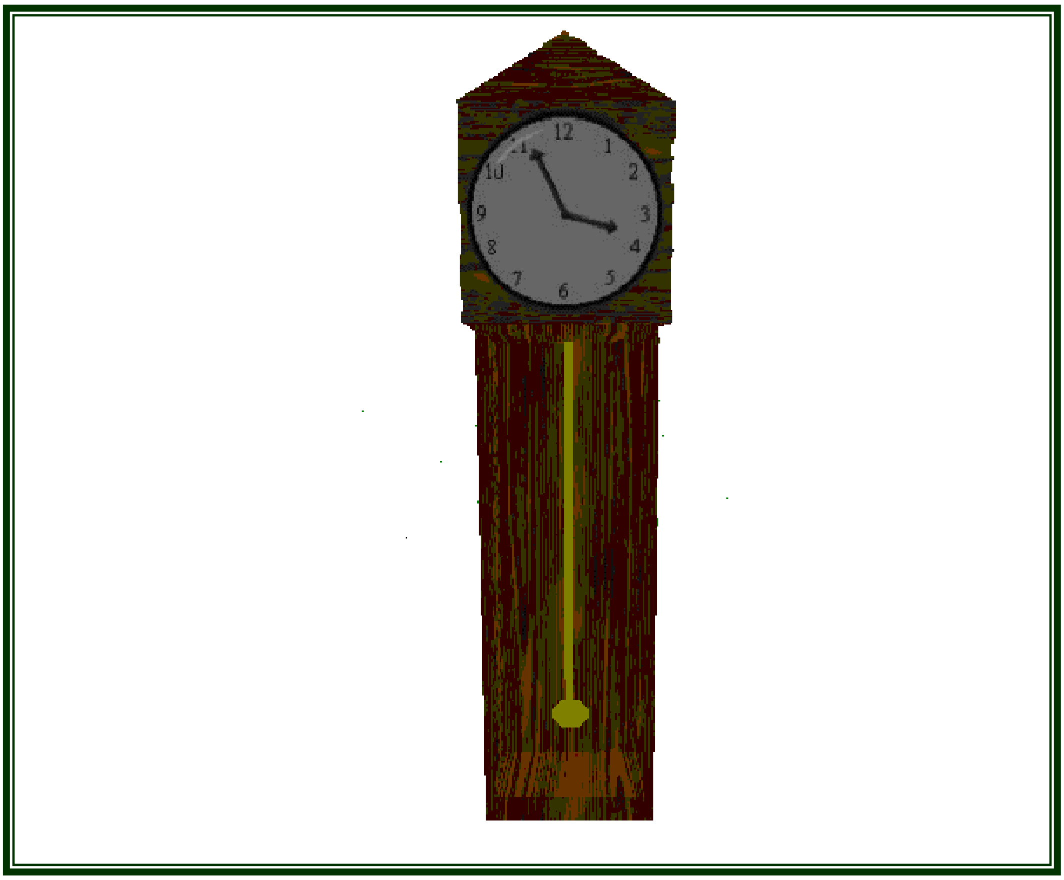
- Alıştırma amaçlı olarak kısa süreliğine diğer bir sanal ortamı incelemek
- Sanal Park içerisinde bulunan yangın musluklarını saymak

5. The 9 Objects used in the Recognition Test

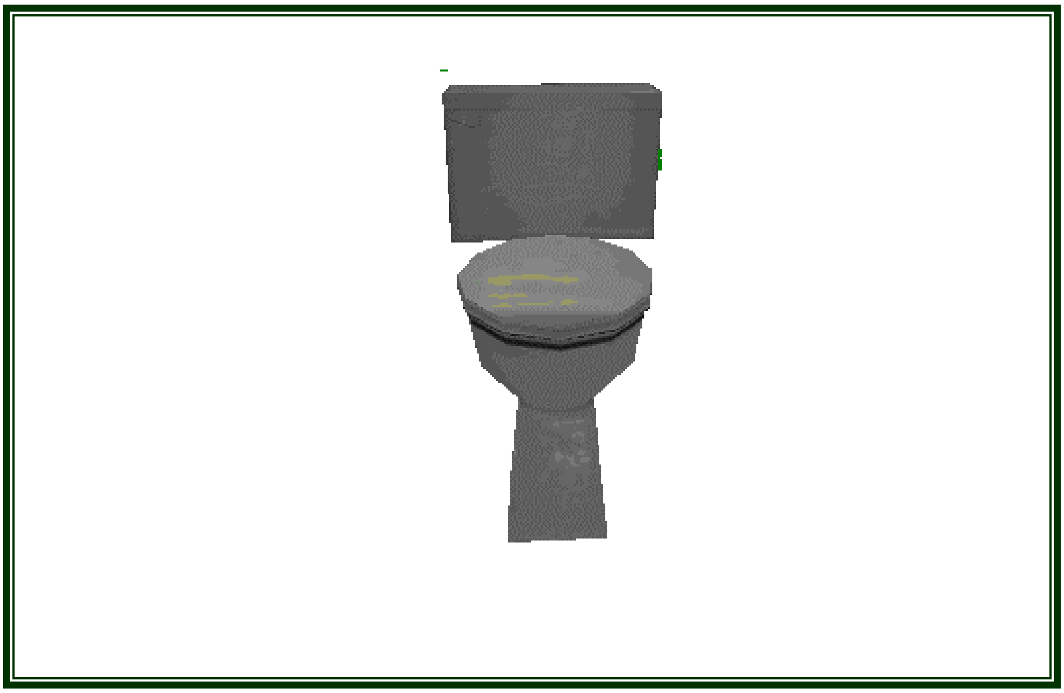


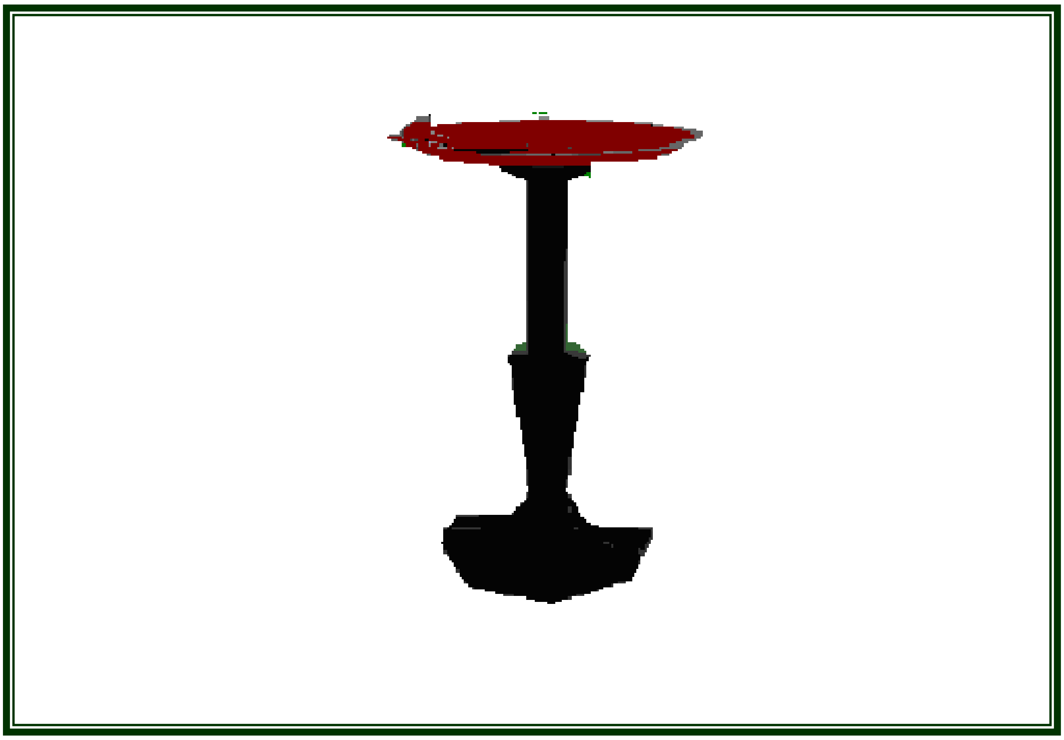





12
1
2
3
4
5
6
7
8
9
10
11

6. The 9 Distracter Objects used in the Recognition Test





APPENDIX B

The result tables obtained from SPSS

1. Age distribution of the participants

N	Valid	60
	Missing	0
Mean		23,58
Std. Error of Mean		,337
Std. Deviation		2,612
Variance		6,823
Range		12
Minimum		18
Maximum		30

2. Gender distribution of the participants

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	female	23	38,3	38,3	38,3
	male	37	61,7	61,7	100,0
	Total	60	100,0	100,0	

3. Class distribution of the participants

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Junior	8	13,3	13,3	13,3
	Senior	35	58,3	58,3	71,7
	Ms	1	1,7	1,7	73,3
	PhD	16	26,7	26,7	100,0
	Total	60	100,0	100,0	

4. Department distribution of the participants

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	CEIT	35	58,3	58,3	58,3
	CE	15	25,0	25,0	83,3
	EE	4	6,7	6,7	90,0
	FDE	1	1,7	1,7	91,7
	IR	2	3,3	3,3	95,0
	IS	1	1,7	1,7	96,7
	MIS	1	1,7	1,7	98,3
	COGS	1	1,7	1,7	100,0
	Total	60	100,0	100,0	

5. ANOVA Results for Cognitive Map Formation for Three Experimental Groups

Tests of Between-Subjects Effects

Dependent Variable: map score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3562,433(a)	2	1781,217	108,873	,000
Intercept	15974,017	1	15974,017	976,375	,000
Group	3562,433	2	1781,217	108,873	,000
Error	932,550	57	16,361		
Total	20469,000	60			
Corrected Total	4494,983	59			

a R Squared = ,793 (Adjusted R Squared = ,785)

Multiple Comparisons

Dependent Variable: map score
Scheffe

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Group-1	Group-2	10,85(*)	1,279	,000	7,64	14,06
	Group-3	18,80(*)	1,279	,000	15,59	22,01
Group-2	Group-1	-10,85(*)	1,279	,000	-14,06	-7,64
	Group-3	7,95(*)	1,279	,000	4,74	11,16
Group-3	Group-1	-18,80(*)	1,279	,000	-22,01	-15,59
	Group-2	-7,95(*)	1,279	,000	-11,16	-4,74

Based on observed means.
* The mean difference is significant at the ,05 level.

map score

Scheffe

Group	N	Subset 1	2	3
Group-3	20	7,40		
Group-2	20		15,35	
Group-1	20			26,20
Sig.		1,000	1,000	1,000

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = 16,361.
a Uses Harmonic Mean Sample Size = 20,000.
b Alpha = ,05.

6. ANCOVA Results for Cognitive Map Formation for Three Experimental Groups

Tests of Between-Subjects Effects

Dependent Variable: map score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3909,138(a)	5	781,828	72,065	,000
Intercept	105,361	1	105,361	9,712	,003
time	326,321	1	326,321	30,079	,000
comp_exp	2,479	1	2,479	,228	,635
comp_use	22,570	1	22,570	2,080	,155
Group	1788,495	2	894,247	82,427	,000
Error	585,846	54	10,849		
Total	20469,000	60			
Corrected Total	4494,983	59			

a R Squared = ,870 (Adjusted R Squared = ,858)

7. ANOVA Results for Object Recognition for Three Experimental Groups

Tests of Between-Subjects Effects

Dependent Variable: object_score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	79,300[a]	2	39,650	13,525	,000
Intercept	1269,600	1	1269,600	433,077	,000
group	79,300	2	39,650	13,525	,000
Error	167,100	57	2,932		
Total	1516,000	60			
Corrected Total	246,400	59			

a. R Squared = ,322 (Adjusted R Squared = ,298)

Multiple Comparisons

Dependent Variable: object_score
Scheffe

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Group1	Group2	,50	,541	,655	-,86	1,86
	Group3	2,65*	,541	,000	1,29	4,01
Group2	Group1	-,50	,541	,655	-1,86	,86
	Group3	2,15*	,541	,001	,79	3,51
Group3	Group1	-2,65*	,541	,000	-4,01	-1,29
	Group2	-2,15*	,541	,001	-3,51	-,79

Based on observed means.

*. The mean difference is significant at the ,05 level.

object_score

Scheffe[a,b]

group	N	Subset	
		1	2
Group3	20	3,00	
Group2	20		5,15
Group1	20		5,65
Sig.		1,000	,655

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 2,932.

a. Uses Harmonic Mean Sample Size = 20,000.

b. Alpha = ,05.

8. ANCOVA Results for Object Recognition for Three Experimental Groups

Tests of Between-Subjects Effects

Dependent Variable: object_score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	83,640[a]	3	27,880	9,593	,000
Intercept	49,423	1	49,423	17,005	,000
time	4,340	1	4,340	1,493	,227
group	40,120	2	20,060	6,902	,002
Error	162,760	56	2,906		
Total	1516,000	60			
Corrected Total	246,400	59			

a. R Squared = ,339 (Adjusted R Squared = ,304)

Tests of Between-Subjects Effects

Dependent Variable: object_score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	85,467[a]	4	21,367	7,302	,000
Intercept	3,624	1	3,624	1,239	,271
comp_use	,774	1	,774	,265	,609
comp_exp	6,087	1	6,087	2,080	,155
group	70,060	2	35,030	11,972	,000
Error	160,933	55	2,926		
Total	1516,000	60			
Corrected Total	246,400	59			

a. R Squared = ,347 (Adjusted R Squared = ,299)

9. ANOVA Results for Participants' Memory for the Locations of Objects for Three Experimental Groups

Tests of Between-Subjects Effects

Dependent Variable: loc_score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	93,900[a]	2	46,950	13,975	,000
Intercept	576,600	1	576,600	171,625	,000
group	93,900	2	46,950	13,975	,000
Error	191,500	57	3,360		
Total	862,000	60			
Corrected Total	285,400	59			

a. R Squared = ,329 (Adjusted R Squared = ,305)

Multiple Comparisons

Dependent Variable: loc_score

Scheffe

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Group1	Group2	,45	,580	,741	-1,01	1,91
	Group3	2,85*	,580	,000	1,39	4,31
Group2	Group1	-,45	,580	,741	-1,91	1,01
	Group3	2,40*	,580	,001	,94	3,86
Group3	Group1	-2,85*	,580	,000	-4,31	-1,39
	Group2	-2,40*	,580	,001	-3,86	-,94

Based on observed means.

*. The mean difference is significant at the ,05 level.

loc_score

Scheffe[a,b]

group	N	Subset	
		1	2
Group3	20	1,35	
Group2	20		3,75
Group1	20		4,20
Sig.		1,000	,741

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 3,360.

a. Uses Harmonic Mean Sample Size = 20,000.

b. Alpha = ,05.

10. ANCOVA Results for Participants' Memory for the Locations of Objects for Three Experimental Groups

Tests of Between-Subjects Effects

Dependent Variable: loc_score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	102,748[a]	3	34,249	10,501	,000
Intercept	10,359	1	10,359	3,176	,080
time	8,848	1	8,848	2,713	,105
group	42,513	2	21,256	6,517	,003
Error	182,652	56	3,262		
Total	862,000	60			
Corrected Total	285,400	59			

a. R Squared = ,360 (Adjusted R Squared = ,326)

Tests of Between-Subjects Effects

Dependent Variable: loc_score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	97,792[a]	4	24,448	7,167	,000
Intercept	1,052	1	1,052	,308	,581
comp_use	,319	1	,319	,093	,761
comp_exp	2,022	1	2,022	,593	,445
group	87,997	2	43,998	12,899	,000
Error	187,608	55	3,411		
Total	862,000	60			
Corrected Total	285,400	59			

a. R Squared = ,343 (Adjusted R Squared = ,295)

11. ANOVA Results for Rejecting Distracter Objects in Object Recognition for Three Experimental Groups

Tests of Between-Subjects Effects

Dependent Variable: dist_score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2,033[a]	2	1,017	,734	,484
Intercept	3360,017	1	3360,017	2425,851	,000
group	2,033	2	1,017	,734	,484
Error	78,950	57	1,385		
Total	3441,000	60			
Corrected Total	80,983	59			

a. R Squared = ,025 (Adjusted R Squared = -,009)

Multiple Comparisons

Dependent Variable: dist_score
Scheffe

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Group1	Group2	,25	,372	,799	-,69	1,19
	Group3	-,20	,372	,866	-1,14	,74
Group2	Group1	-,25	,372	,799	-1,19	,69
	Group3	-,45	,372	,486	-1,39	,49
Group3	Group1	,20	,372	,866	-,74	1,14
	Group2	,45	,372	,486	-,49	1,39

Based on observed means.

dist_score

Scheffe[a,b]

group	N	Subset 1
Group2	20	7,25
Group1	20	7,50
Group3	20	7,70
Sig.		,486

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 1,385.

a. Uses Harmonic Mean Sample Size = 20,000.

b. Alpha = ,05.

12. ANCOVA Results for Rejecting Distracter Objects in Object Recognition for Three Experimental Groups

Tests of Between-Subjects Effects

Dependent Variable: dist_score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4,754[a]	3	1,585	1,164	,332
Intercept	172,124	1	172,124	126,446	,000
time	2,720	1	2,720	1,998	,163
group	4,033	2	2,016	1,481	,236
Error	76,230	56	1,361		
Total	3441,000	60			
Corrected Total	80,983	59			

a. R Squared = ,059 (Adjusted R Squared = ,008)

Tests of Between-Subjects Effects

Dependent Variable: dist_score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4,228[a]	4	1,057	,757	,557
Intercept	50,230	1	50,230	35,993	,000
comp_exp	,200	1	,200	,143	,707
comp_use	2,132	1	2,132	1,528	,222
group	2,991	2	1,496	1,072	,349
Error	76,755	55	1,396		
Total	3441,000	60			
Corrected Total	80,983	59			

a. R Squared = ,052 (Adjusted R Squared = -,017)

13. ANOVA Results for Cognitive Map Formation according to the Participants' Game Experience

Between-Subjects Factors

		Value Label	N
game	0	never	9
	1	rarely	21
	2	sometimes	18
	3	frequently	12

Tests of Between-Subjects Effects

Dependent Variable: map_score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	289,114[a]	3	96,371	1,283	,289
Intercept	14504,458	1	14504,458	193,123	,000
game	289,114	3	96,371	1,283	,289
Error	4205,869	56	75,105		
Total	20469,000	60			
Corrected Total	4494,983	59			

a. R Squared = ,064 (Adjusted R Squared = ,014)

Multiple Comparisons

Dependent Variable: map_score
Scheffe

(I) game	(J) game	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
never	rarely	-,95	3,453	,994	-10,90	9,00
	sometimes	-2,33	3,538	,932	-12,53	7,86
	frequently	-6,42	3,821	,428	-17,43	4,60
rarely	never	,95	3,453	,994	-9,00	10,90
	sometimes	-1,38	2,784	,970	-9,40	6,64
	frequently	-5,46	3,136	,394	-14,50	3,58
sometimes	never	2,33	3,538	,932	-7,86	12,53
	rarely	1,38	2,784	,970	-6,64	9,40
	frequently	-4,08	3,230	,662	-13,39	5,23
frequently	never	6,42	3,821	,428	-4,60	17,43
	rarely	5,46	3,136	,394	-3,58	14,50
	sometimes	4,08	3,230	,662	-5,23	13,39

Based on observed means.

map_score

Scheffe[a,b,c]

game	N	Subset
		1
never	9	14,00
rarely	21	14,95
sometimes	18	16,33
frequently	12	20,42
Sig.		,308

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 75,105.

a. Uses Harmonic Mean Sample Size = 13,440.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = ,05.

14. ANOVA Results for Object Recognition according to the Participants' Game Experience

Tests of Between-Subjects Effects

Dependent Variable: object_score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	25,642[a]	3	8,547	2,168	,102
Intercept	1066,197	1	1066,197	270,464	,000
game	25,642	3	8,547	2,168	,102
Error	220,758	56	3,942		
Total	1516,000	60			
Corrected Total	246,400	59			

a. R Squared = ,104 (Adjusted R Squared = ,056)

Multiple Comparisons

Dependent Variable: object_score
Scheffe

(I) game	(J) game	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
never	rarely	-1,51	,791	,314	-3,79	,77
	sometimes	-1,89	,811	,156	-4,23	,45
	frequently	-1,97	,876	,179	-4,50	,55
rarely	never	1,51	,791	,314	-,77	3,79
	sometimes	-,38	,638	,949	-2,22	1,46
	frequently	-,46	,718	,936	-2,54	1,61
sometimes	never	1,89	,811	,156	-,45	4,23
	rarely	,38	,638	,949	-1,46	2,22
	frequently	-,08	,740	1,000	-2,22	2,05
frequently	never	1,97	,876	,179	-,55	4,50
	rarely	,46	,718	,936	-1,61	2,54
	sometimes	,08	,740	1,000	-2,05	2,22

Based on observed means.

object_score

Scheffe[a,b,c]

game	N	Subset
		1
never	9	3,11
rarely	21	4,62
sometimes	18	5,00
frequently	12	5,08
Sig.		,097

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 3,942.

a. Uses Harmonic Mean Sample Size = 13,440.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = ,05.

15. ANOVA Results for Participants' Memory for the Locations of Objects according to the Participants' Game Experience

Tests of Between-Subjects Effects

Dependent Variable: loc_score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	23,567[a]	3	7,856	1,680	,182
Intercept	497,373	1	497,373	106,376	,000
game	23,567	3	7,856	1,680	,182
Error	261,833	56	4,676		
Total	862,000	60			
Corrected Total	285,400	59			

a. R Squared = ,083 (Adjusted R Squared = ,033)

Multiple Comparisons

Dependent Variable: loc_score
Scheffe

(I) game	(J) game	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
never	rarely	-,56	,861	,936	-3,04	1,93
	sometimes	-1,61	,883	,353	-4,16	,93
	frequently	-1,56	,953	,453	-4,30	1,19
rarely	never	,56	,861	,936	-1,93	3,04
	sometimes	-1,06	,695	,516	-3,06	,95
	frequently	-1,00	,782	,654	-3,26	1,26
sometimes	never	1,61	,883	,353	-,93	4,16
	rarely	1,06	,695	,516	-,95	3,06
	frequently	,06	,806	1,000	-2,27	2,38
frequently	never	1,56	,953	,453	-1,19	4,30
	rarely	1,00	,782	,654	-1,26	3,26
	sometimes	-,06	,806	1,000	-2,38	2,27

Based on observed means.

loc_score

Scheffe[a,b,c]

game	N	Subset
		1
never	9	2,11
rarely	21	2,67
frequently	12	3,67
sometimes	18	3,72
Sig.		,303

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 4,676.

a. Uses Harmonic Mean Sample Size = 13,440.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = ,05.

16. ANOVA Results for Rejecting Distracter Objects in Object Recognition according to the Participants' Game Experience

Tests of Between-Subjects Effects

Dependent Variable: dist_score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6,329[a]	3	2,110	1,582	,204
Intercept	3036,012	1	3036,012	2277,372	,000
game	6,329	3	2,110	1,582	,204
Error	74,655	56	1,333		
Total	3441,000	60			
Corrected Total	80,983	59			

a. R Squared = ,078 (Adjusted R Squared = ,029)

Multiple Comparisons

Dependent Variable: dist_score
Scheffe

(I) game	(J) game	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
never	rarely	-,14	,460	,992	-1,47	1,18
	sometimes	,17	,471	,989	-1,19	1,53
	frequently	-,75	,509	,542	-2,22	,72
rarely	never	,14	,460	,992	-1,18	1,47
	sometimes	,31	,371	,874	-,76	1,38
	frequently	-,61	,418	,554	-1,81	,60
sometimes	never	-,17	,471	,989	-1,53	1,19
	rarely	-,31	,371	,874	-1,38	,76
	frequently	-,92	,430	,221	-2,16	,32
frequently	never	,75	,509	,542	-,72	2,22
	rarely	,61	,418	,554	-,60	1,81
	sometimes	,92	,430	,221	-,32	2,16

Based on observed means.

dist_score

Scheffe[a,b,c]

game	N	Subset
		1
sometimes	18	7,17
never	9	7,33
rarely	21	7,48
frequently	12	8,08
Sig.		,249

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 1,333.

a. Uses Harmonic Mean Sample Size = 13,440.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = ,05.

17. T-Test Results for Cognitive Map Formation According to Participants' Gender

		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
map score	Equal variances assumed	,876	,353	,933	58	,354	2,166	2,320	-2,479	6,810
	Equal variances not assumed			,982	54,102	,330	2,166	2,205	-2,254	6,586

18. T-Test Results for Object Recognition According to Participants' Gender

Independent Samples Test

		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
object_score	Equal variances assumed	,299	,586	-,620	58	,537	-,338	,545	-1,430	,753
	Equal variances not assumed			-,633	49,764	,530	-,338	,535	-1,413	,736

19. T-Test Results for Memory for the Locations of Objects According to Participants' Gender

Independent Samples Test

		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
loc_score	Equal variances assumed	,413	,523	,806	58	,423	,472	,586	-,700	1,645
	Equal variances not assumed			,833	51,616	,409	,472	,567	-,666	1,610

20. T-Test Results for Rejecting Distracter Objects According to Participants' Gender

Independent Samples Test

		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
dist_score	Equal variances assumed	1,382	,244	,199	58	,843	,062	,314	-,566	,690
	Equal variances not assumed			,188	39,037	,852	,062	,331	-,607	,731