

EFFECTS OF WAY FINDING AFFORDANCES ON USABILITY OF VIRTUAL
WORLD ENVIRONMENTS IN TERMS OF USERS' SATISFACTION,
PERFORMANCE, AND MENTAL WORKLOAD: EXAMINATION BY EYE-
TRACKING AND FNIR DEVICE

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SATISFACTION, PERFORMANCE, AND MENTAL WORKLOAD:
EXAMINATION BY EYE-TRACKING AND FNIR DEVICE**

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ABSTRACT

EFFECTS OF WAY FINDING AFFORDANCES ON USABILITY OF VIRTUAL
WORLD ENVIRONMENTS IN TERMS OF USERS' SATISFACTION,
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TRACKING AND FNIR DEVICE

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This study aims to test the effects of different way finding affordances on the usability of METU virtual campus built in Second Life virtual world in terms of users' satisfaction, performance and mental workload. This study was conducted with 36 participants who are students at the Middle East Technical University. Participants were randomly put on of the five groups namely map, signboard, voice and agent groups and a control group. The participants were given navigational tasks in METU virtual campus within Second Life. In the experiment, the eye movements of the participants were examined with eye tracking tool in order to determine the areas which participants paid attention most. Also mental work load in their prefrontal cortex was examined with fNIR device. There was no significant difference among groups in terms of satisfaction, however; there were significant difference among groups in terms of task completion accuracy, time, length, navigation cue gaze duration and mental workload. Agent group has the highest accuracy score, map group has the highest time, length and navigation cue gaze

duration score. Moreover, agent group has the highest mental workload but control group has the lowest mental workload.

The results of the tests were used to provide guidance for the design of way finding affordances in METU virtual campus.

Keywords: Virtual world, usability, eye tracking, fNIR, mental workload, way finding cues.

ÖZ

3 BOYUTLU SANAL ORTAMLARIN YÖN BULMA ARAÇLARININ KULLANILABİLİRLİK ÜZERİNDEKİ ETKİSİNİN KULLANICI MEMNUNİYETİ, PERFORMANSI VE BİLİŞSEL YÜK AÇISINDAN, GÖZ İZLEME VE FNIR AYGITI İLE TEST EDİLMESİ

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Yüksek Lisans, Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü

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Bu çalışmanın amacı Second Life ortamında yer alan ODTÜ sanal kampüsünün kullanılabilirliği üzerinde yön bulma araçlarının etkisini kullanıcıların memnuniyeti, performansı ve bilişsel yük açısından test etmektir. Bu çalışma Orta Doğu Teknik Üniversitesi öğrencisi 36 kişi ile gerçekleştirildi. Katılımcılar rast gele harita, levha, ses, ajan ve control gruplarına atandı. Çalışmada katılımcılara ODTÜ sanal kampüsünde yer,yöne bulma görevleri verildi. Katılımcılar görevleri gerçekleştirirken göz hareketleri, göz izleme cihazı ile incelendi. Ayrıca, katılımcıların ön beyinlerinde oluşacak bilişsel yüklenme alanları fNIR cihazı ile taranarak hangi alana daha çok bilişsel yüklenme olduğu belirlendi. Memnuniyet puanına açısından gruplar arasında anlamlı bir fark gözlemlenmedi. Fakat, görevi başarma, görev tamamlama mesafesi, zamanı, yer/yön bulma araçlarına bakış süreleri ve bilişsel yük açısından gruplar arasında anlamlı farklar gözlemlendi. Ajan grubu görevi başarma puanı açısından en yüksek puan ortalamasını elde etti, fakat, harita grubu görev tamamlama mesafesi, zamanı ve yer/yön belirtme araçlarına bakış süresi açısından en yüksek puan ortalamalarını aldığı gözlemlendi. Ayrıca, aja

grubunun bilişsel yük ortalamasının diğer gruplardan yüksek olduğu fakat control grubunun en düşük bilişsel yüke puan ortalamasına sahip olduğu gözlemlendi.

Bu çalışmanın sonuçları, ODTÜ sanal kampüsündeki yön bulma araçlarının tasarımına rehberlik etmesi amacı ile kullanılacaktır.

Anahtar kelimeler: Sanal dünya, kullanılabilirlik, göz izleme, fNIR, bilişsel yük, yer/yön belirtme araçları.

This work is dedicated to;

My Family

&

My Beautiful Fiancée and Love of My Life

Ceyda Tekin

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LIST OF ABBREVIATIONS

2D	: Two dimensional
3D	: Three dimensional
AWEDU	: The Active Worlds Educational Universe
NASA	: The National Aeronautics and Space Administration
CPU	: Central Processing Unit
HCI	: Human-Computer Interaction
fNIR	: Functional Near-Infrared Spectroscopy
ISO	: International Organization for Standardization
ESPRIT	: European Strategic Program on Research in Information Technology
MRI	: Magnetic Resonance Imaging
MEG	: Magneto encephalography
fMRI	: Functional Magnetic Resonance Imaging
PET	: Positron Emission Tomography
EEG	: Electroencephalography
SQUID	: Superconducting Quantum Interference Devices
SPECT	: Single Photon Emission Computerized Tomography

MSI	: Magnetic Source Images
Oxy-Hb	: Oxygenated Hemoglobin
Deoxy-Hb	: Deoxygenated Hemoglobin
fNIR	: Functional Near-infrared Spectroscopy
LED	: Light-Emitting Diode
CW	: Continuous Wave
ERP	: Event-Related Potential
BOLD	: Blood-Oxygen-Level-Dependent
SNR	: Signal-to-Noise Ratio
TCT	: Task Completion Time
TTCT	: Total Task Completion Time
TCL	: Task Completion Length
TTCL	: Total Task Completion Length
TTCA	: Total Task Completion Accuracy
US	: User Satisfaction
MWL	: Mental Work Load
SSGD	: Standard Signboard Gaze Duration
TSSGD	: Total Standard Signboard Gaze Duration
NCGD	: Navigation Cue Gaze Duration
TNCGD	: Total Navigation Cue Gaze Duration

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The progress in technology accelerates the progress in communication technologies. Education is one of the major domains which benefits from this progress. Distance education systems developed rapidly for the last decades. Although the instruction still dominated by “chalk and talk paradigm” (Gorgievski et al., 2005), flexibility in time and location both for the teacher and the student increased the demand for distance education systems. Especially after the invention of the Internet, there is no need for teachers and students to become together simultaneously. The computer infrastructures have been developed and become accessible for everyone. Following these developments, virtual worlds emerged. Virtual worlds are Internet based environments where people represent themselves through an avatar and being able to interact with the other avatars. People sense that they exist in that virtual environment socially and physically.

As technology develops, complexity level of the systems increases and efficient use gets harder. No matter how complex the systems are, users always ask for systems easy to use. Therefore, for such demands of the users, the concept of usability emerged in early 1970s as “ease of use of a system or product”. In this study, the effects of way finding cues on the usability of the virtual worlds were investigated.

Among quite a number of definitions, Mack and Nielsen (1994) introduced a broad definition for usability as how easy it is for users to learn a system, how efficiently they can use it once they have learned it, and how pleasant it is to use. The trend of

making use of usability testing after development of any system or product bounced in 1990s. However; testing methods were not sufficient, because of their subjective and not quantifiable nature, since the participants were required to respond to specified questions. These questions were designed to measure some usability criteria such as time for accomplishing given task, or pleasure or error rate etc. As a result, for a better healthy evaluation of the system or product, various technologies have been developed including eye-tracking (Nielsen, 1993).

Eye tracking is a technique that records eye movements and allows testers to determine visual attention points on the interface (Namahn, 2001). There are two types of eye tracking technique called as intrusive technique and non-intrusive technique. While intrusive eye-tracking technique includes physical contact between the apparatus and the user; non-intrusive systems do not include physical contact (Weigle and Banks, 2008). At first, the usage area of eye tracking expanded to usability studies in 2D websites, and then 3D environments developed. Yet, 3D environments were not issued mostly in usability studies using eye-tracking device. Virtual worlds as 3D environments are covered within the range of this thesis. A virtual world is broadly defined as “A *synchronous, persistent network of people, represented as avatars, facilitated by networked computers.*” (Bell, 2008). There exist too many examples for a virtual world recently which are developed by different organizations. They have various implementation areas such as training and education, simulation, medicine, military, science, art and etc.

In addition to eye-tracking device; a brain sensing technique, fNIR, is used within the study. In general, brain sensing technologies provide valuable information about the cognitive state of the user of an interface and measure workload. Functional Near-infrared Spectroscopy (fNIR), uses near-infrared light in order to analyze hemodynamic changes and find out active regions of the brain. It is not encountered in the literature within usability studies, instead, is used in workload studies (Hirschfield et al., 2009). Using fNIR as complementary to eye tracking in usability studies is advantageous also because it is non-invasive, portable and easy-to-use. Because fNIR was not used together with eye tracking in usability studies, it would be a new emerging implementation technique which was expected to be developed in

the future studies. In this study, fNIR and eye tracking device were utilized simultaneously.

The first time when the people go either to physical or virtual environment, naturally they have no idea about that place. They recognize and learn the environment over time, and as a result, they accomplish their work more quickly compared the previous periods in that environment. Learning the environment is labeled as “creation of cognitive map”. (Goldin & Thorndyke, 1982) When people enter in an environment at first time, they have no cognitive map in their mind. For this reason they use certain way finding tools, such as signs or something that significant for them, a tall building or a strange sign. Wang, Zhu, Mao (2007) emphasize the important effect of the description of environment with landmark information. With all these structured or unstructured signs, they try to create cognitive map for the environment. Some other examples for these kind of navigation tools are; signboards, sheets or maps, etc.

In a 3D virtual environment, the users observe the environment from different perspectives, mainly *egocentric* and *exocentric*. A user can use both of them and combine the perceptions in the exploration period. In egocentric view, the user is embedded in virtual environment and s/he interacts from inside the environment whereas s/he interacts from outside in exocentric view (Wickens and P. Baker, 1995). In this way, they recognize the environment and develop their “navigational awareness”. Navigational awareness is questioned about whether is it possible or easy to recognize the current location in a large environment or to determine the locations of other objects (Satalich, 1995). Navigational awareness is acquired by having navigational knowledge. In order to acquire navigational knowledge in a new large-space environment, a constructive process has to be completed. Siegel & White (1975) explain this process as their “Sequential and Hierarchical” model which is explained in detail further.

Navigation is not only a physical change of direction in an environment, but also a cognitive event. It is defined as “the process by which people control their movement using environmental cues and artificial aids such as maps so that they can achieve their goals without getting lost” (Darken & Sibert, 1993, p157). Navigation consists

of two main components: *Way finding* is the cognitive component of navigation, and *travel* or *locomotion* which refers to the movement/motion and motor component of navigation (Bowman et al., 2004). This study deals with way finding affordances. Downs and Stea (1973) and Satalich (1995) claimed that way finding is achieved in four steps which are orientation, route decision and monitoring and finally recognition of destination. Each step has different effect on the individuals' mental work load.

There are several different way finding affordances. In the study signboard, map, audio cue, and agent are investigated as way finding cues. Signboards, audio cues and agents assist in developing egocentric view, while maps in developing exocentric view. In general, in a 3D virtual environment more than one of these affordances exists. Users prefer using appropriate one in way finding process. In this study the participants were given only one affordance in each experiment. So the effect of that way finding affordance on work load and usability could be investigated.

1.2 Purpose of the Study

This study investigates the usability of 3D environments by measuring the effect of way finding affordances on mental workload in these environments by using eye-tracking and fNIR devices. Moreover, providing suggestions for designing way finding affordances in 3D environments in terms of usability and mental workload parameters is aimed. Besides, deciding which affordance is more effective than others in METU virtual campus is aimed.

1.3 Research Question

What are the effects of way finding affordances, including voice, map, agent, and sign on usability?

What are the effects of way finding affordances, including voice, map, agent, and sign on users' performance in terms of task completion time and length?

What are the effects of way finding affordance, including voice, map, agent, and sign on users' satisfaction?

What are the effects of way finding affordance, including voice, map, agent, and sign on users' mental workload?

1.4 Significance of the Study

As it is pointed out earlier, the number of usability studies in 2D environments exceeds the number of usability studies in 3D environments. Furthermore; questionnaires, which do not provide quantitative data reliable enough, are mostly used for usability testing in 2D and 3D environments. Although the number of studies in 2D environments using eye tracking device in order to test usability are increasing, there are very few usability studies in 3D environments using eye tracking technique. Moreover, there is almost no usability study in 3D environments using fNIR in the literature. Therefore, this thesis is expected to try to fill some of this gap in the literature.

- Several way finding affordances are investigated in the study. This study provides information about which affordance is most effective and how it effects on mental workload. The results may provide suggestions for designers in terms of navigational cues.
- This test provides the answer of whether eye tracking device and fNIR are consistent with each other's result.
- There could be a difference between using eye tracking device solely and with fNIR simultaneously.

For the designers of the virtual worlds, this study aims to provide suggestions while designing virtual environment. Adding a new modality to existing one could provide new understanding for designers and usability experts. The users of the virtual worlds could obtain better and more user friendly interfaces in the long term.

1.4 Organization of Thesis

This chapter explained the background for, the purpose and significance of this thesis. Chapter 2 examines the relevant literature in addition to the definitions of the terms used throughout the thesis.

Chapter 3 describes the experiments and gives information about the virtual environment that the experiments are conducted. Research goals, 3D environment that is investigated, physical equipment, procedure of data collection, study settings, participants, pilot study, limitation of the study and main study are explained in detail.

Chapter 4 consists of demographic data, user questionnaire results, eye tracking and fNIR results' evaluation, and user recommendations.

Finally, Chapter 5 is comprised of a general discussion of results from Chapter 4. A brief summary about the work done and recommendation for further research are covered throughout this chapter.

CHAPTER 2

LITERATURE REVIEW

Throughout this chapter detailed information presented on virtual worlds' definition, common features, used areas, design also, usability and usability evaluation, eye tracking and brain sensing technologies and finally navigation way finding affordances.

2.1 Definition of 3D virtual worlds

The term virtual world has been used widely, but there is not one common definition of it. There are two main prior definitions of a virtual world. Richard Bartle proposed a definition for the "world" as "an environment that its inhabitants regard as being self-contained". Bartle (2004) remarked that a world didn't have to mean an entire planet. Although, "virtual world" was not addressed by Bartle who created text-based virtual worlds in 1970 and 1980s, all latter definitions were set up on the definition of Bartle. Likewise, Bell (2008) agreed that Bartle's definition was lacking of what makes a world virtual one. Another definition is made by Koster as "a virtual world is a spatially based depiction of a persistent virtual environment, which can be experienced by numerous participants at once, who are represented within the space by avatars" (Koster, 2004). Avatar is the visual representation of a user in a multi-user environment (Dickey, 1999). Castronova defined virtual worlds as "crafted places inside computers that are designed to accommodate large numbers of people" (2004). Castronova completed the missing element of Koster's definition, which was the technology. Considering Castronova's definition, a shared document would be a

virtual world because the definition did not cover the ideas of persistence and synchronous communication (Bell, 2008). By inserting essential components into the definition, which were people and their social network, Bell combined these two prior definitions as “A synchronous, persistent network of people, represented as avatars, facilitated by networked computers” (Bell, 2008). A similar definition was also made by Dickey (2005) as “A networked desktop virtual reality in which users move and interact in simulated 3D spaces”.

2.2 Common Features of 3D Virtual Worlds

The users are visually represented by avatars in all 3D virtual environments. In most of the 3D virtual worlds, users have to select their avatar name and gender to subscribe. The gender and name for an avatar cannot be changed after subscription. However, some features such as hair style and clothing could be customized by members. Connection to the virtual worlds requires common procedures for majority of the virtual worlds. A client-server network involves multiple clients connecting to the central server which is the 3D virtual world. A member should have an installed client program in his/her computer to connect virtual world server. Then, the user can access his/her personal account by entering user name and password into client program. Generally, virtual worlds have their own economy and currency. The users in 3D virtual environments are able to create objects and buy/sell them in virtual world's currency. Furthermore, the virtual environments provide opportunity for socialization by activities such as playing games, chatting, having parties, and training.

2.3 Examples for 3D Virtual Worlds

2.3.1 Onverse

Onverse is a free online virtual world developed by Onverse, LLC. “Onverse” is a combination of "online" and "universe." Onverse serves as a social network due to avatars profiles, media sharing, user comments, micro-blogging and an interactive forum in the website. Moreover it is a gaming platform in which the users win

rewards and points to purchase upgraded tools, furniture, pets, clothing and homes, etc. Some games and puzzles require solo completion whereas others require cooperative work. In addition, there exists the Learning Center which includes tutorials that all users are required to complete. While the variety of games in Onverse is increasing continuously, on May 30, 2011, it was announced in forums that a new world is expected to be developed. (Onverse, 2011)

2.3.2 Kaneva

Kaneva is an online 3D virtual world which was founded in 2004 firstly as a massively multi-player online game. Then, similar to other virtual worlds, Kaneva began to offer experiences such as play games, shop, or build your dream home for the users. Moreover, the users are allowed to bring their favorite videos, photos, music, and games into virtual world. It also supports the 2D web browsing and as a result, the users are able to pass from web browser-based social networking experience to the site's connected 3D virtual world. As of June 2011, Kaneva has nearly 187,270 subscribed unique users (SiteTrail, Inc., 2011).

2.3.3 Twinity

Twinity is the first virtual world using real world's city architecture. Berlin, Miami, Singapore, London and New York are the replica cities of Twinity. It was developed by Metaversum GmbH in 2008. One unique feature of Twinity is that members could create and customize their own avatars by using Photofit application. This application allows users to upload their own real photos, then it adapts to avatar face.

2.3.4 Active Worlds

Activeworlds was originally named as AlphaWorld when created by Knowledge Adventures on July 27th, 1995 (Dickey, 1999). Then, Activeworlds was sold to Circle of Fire. Circle of Fire supports as many languages as it does which would be a significant criterion for global users. It is a platform that offers real-time interactive dynamic 3D content over the web. The users can own and build virtual home or any

building in specific areas not requiring background knowledge in 3D design and modeling. In addition, Active Worlds have options for importing unique and personal artwork and images. Even, the users are allowed to create their own virtual structures using objects in Active Worlds.

The users in Activeworlds possess unique identity which they attach to their land and building in Activeworlds. This identity allows users to recognize and contact with each other (Dickey, 1999). Users contact with other users in their list and send and receive remote messages called telegrams. Thereby, a degree of control and trust among users is established.

Activeworlds also support playing online games, shopping, travelling, Internet-based advertising, performing interactive product demos, supporting customer relationship management and distance learning, etc. Activeworlds provides a new dimension for education. For instance, The Active Worlds Educational Universe (AWEDU) was launched. AWEDU is available to educational institutions, teachers, students, and individual programs in a focused setting. AWEDU gives opportunity to exploration of new concepts, theories, designs, and paradigms which in turn results in lower costs. AWEDU hosts from architecture departments to science labs. Another education platform of Activeworlds is River City in which students travel back in time to address 19th century problems. Students are required to work collaboratively to help residents of River City in their problems. They form and test hypotheses, develop controlled experiments and make decisions in a virtual environment.

2.3.6 Second Life

Second Life is an online virtual world developed by Linden Lab and was launched on June 23, 2003. Linden Lab changed the old hardware version into Second Life software application in which people called “Residents” interact with each other through avatars. The users choose avatars that fit their personality, gender, culture, ethnicity, fitness, age, etc. or even avatars in the form of an animal, vegetable, mineral or a combination of these. These avatars embody users with gestures, emotions, actions, and serve as camera and navigation for users. Over the top of

avatars the users' names are shown as identity. Second Life provides Welcome Island for the new subscribers to teach them quickly basics of navigation and communication.

Exploring the world, meeting with other residents, participating in individual or group activities, and creating and trading virtual property and services with one another are some of the activities present in real life that can be conducted also in Second Life. Second Life also supports playing online games, shopping, travelling; Internet based advertising and distance learning, etc. Second Life has a currency in Linden dollars which can be purchased with US dollars and other currencies. The user can trade virtual goods such as buildings, vehicles, devices, animations, clothing, skin, hair, jewelry, flora and fauna, and works of art. In addition, the virtual services that are offered include camping, wage labor, business management, entertainment and custom content creation.

Second Life client program supports multiple platforms such as Windows XP, Mac OS X, Linux, Solaris and OpenSolaris which addresses more customer segments. As of May 2011, avatars who signed in Second life exceeded 23 million. Smeet, Smallworlds, Uthervers, Entropia Universe, Blue Mars, Moove, IMVU are just a few examples of other growing virtual worlds.

2.4 Use of 3D Virtual Worlds

Within last ten years there have been huge technological developments in communication. Today almost everyone has a personal computer and has access to internet. In addition, bandwidths are ten times faster. With the development of these changes, virtual worlds have emerged. An important question to be responded is that why these virtual worlds should be utilized in our lives. The virtual worlds should be utilized because they are cheap, accessible and not time consuming. They allow simulations and changes in the environment. Expensive or dangerous processes can be simulated in a virtual world. Optimal production can be designed and found via virtual worlds.

2.4.1 Arts

Second Life serves as an environment that allows artists to create and display their art works to all audiences across the world. Via this service, the artists find the opportunity to meet with real life customers. As of August 2007, there exist 1,000 galleries in Second Life. The creations in Second Life are not tangible, not requiring any cost for reproduction. While time to market takes months to years for a real life art work, it takes only seconds to minutes for a virtual art work. Moreover, Second Life environment is a creative medium for many artists because it offers easy to use and not existing in real life modeling tools. Live music performances, theatre, virtual dances are some other activities that can be conducted in second life (Minsky, 2007).

2.4.2 Education and Science

Computer based training and e-learning became the new trends in this century, because web technology brought new changes for education and training. Virtual worlds prepare medium for developing game based learning experiences fast and cheaply (Helmer and Light, 2007). The virtual worlds are used for scientific research, collaboration and data visualization (Lang and Bradley, 2009). High social environment of 3D virtual worlds leads to high user engagement (Helmer and Light, 2007). In virtual environments; a social context for learning and a sense of presence are provided. In this manner, emotional involvement and engagement of students might be achieved (Fominkyh et al., 2008). The users share ideas, plan future projects on the educational content in 3D environment. As a result, new ideas are being enforced through conversations, meetings, 3D visualizations etc. Steinkuehler and Squire (2009) emphasize that because the students make comments, synthesis and analysis after collection of data, virtual worlds support production of new forms of information in addition to access of information. Therefore, learners are not only information consumers but also information producers. The good part is that the users are not required to have any technical knowledge to use virtual worlds and in turn to both consume and produce information. When the users create the content, a highly diverse and culturally rich environment appears (Helmer and Light, 2007). The virtual worlds offer many people the opportunity to work on problems

collectively which bears different strategies. Kolb (1984) mentioned about a learning cycle in his work *Experiential Learning: Experience as the Source of Learning and Development*. Johnson and Levine (2008) pointed out that discovering new applications in virtual world and putting them into practice involves the highest level of this learning cycle. These kind of new experiences in virtual environment in turn start the cycle again. Since virtual worlds and the real world resemble to each other, visitors have the opportunity to anticipate the effect of their actions within the real world.

As focusing on learning, the virtual campus, a type of educational virtual world, can be defined as an environment that represents a university and provides users with a special place and a set of tools for teaching (Fominkyh et al., 2008). The users share the educational content, benefit from educational simulations and demonstrations, and collaborative learning is supported. They mostly provide rich media such as power point presentation, video, audio, chat, interactive boards, e-books, learning management systems, external web site links, etc. Furthermore, virtual campuses might include virtual laboratories, museums, student galleries and workshops, personal offices.

Although different universities use different platforms, extensively used platform today for virtual campuses is Second Life. California State University, Harvard University, Ohio State University, University of Hertfordshire and University of Sussex are a few of approximately 400 universities and colleges that have a presence in Second Life. Not only whole institutions are presented in Second Life but also individual classes exist.

Besides formal education, virtual worlds provide necessary tools and environments for informal education, too. Any type of training which can be moved to digital platform can be given through virtual worlds. Some example types of training might be customer and supplier education, ethics training, recruiting, soft skills training, public sector finance according to Plensky. Because training subjects such as mental or sexual health, etc. is relatively sensitive, training through virtual world platforms is suggested (Helmer and Light, 2007).

Virtual worlds provide not only educational environment, but also community of practice for special purposes. There is a specialized continent for science in Second Life, which is called SciLand, and islands such as Genome Island, American Chemical Society's Island. One third scale of Victoria Crater in Mars is modeled in SciLand by NASA. The current weather above U.S. Continental can be observed via virtual map. Flying through a hurricane or watching how a tsunami is formed or learning how atmospheric data is collected with a balloon is a possible simulation in SciLand.

Furthermore, interactive laboratory environment is provided in virtual worlds. Both informational areas such as exhibits comparing the organization of the human genome with that of the chimpanzee, and experimental areas such as construction of experiments of crossing green peas with yellow peas exist or creating own genetic models exist (Clark, 2008). The virtual worlds provide secure and cheap environment in terms of physical experiences due to virtualization of the real world. For instance, to make a chemistry or physics experiment in real world may require laboratory environment, necessary tools and expensive substances, and those substances and tools can only be used at once. And also during these experiments unexpected incidents may occur due to human errors. On the other hand, in virtual world environment, these experiments can be conducted in a much cheaper environment since laboratory tools and substances are reusable and in a much secure environment since it is a virtual environment. In fact, the virtual worlds offer more than security and cheapness; also they provide augmented capabilities such as flying and augmented realities such as expanding time which are not possible in real world. Additionally, every user including disabled users share the same physical conditions in virtual worlds.

2.5 Design of 3D virtual worlds

There are two major areas of virtual world design. The first one is hardware and software design and the second one is 3D environment architecture and interaction design (Gu et al., 2007). The former one is related with the design of infrastructure

components such as CPU, network connection and bandwidth, operating system, physical engine, programming language, etc.

In the very first versions of virtual worlds, what was critical is information due to less developed technology. Benedikt (1991) addresses the importance of participants and claims design principles of dimensionality, continuity, curvature, density and limits. Then, Morningstar and Farmer (1991) realized technology was as important as information in order to share information through an environment.

The earlier designs of 3D virtual worlds were mostly related with architectural design. Because of their place metaphor, earlier designs only aimed to copy the counterpart of the physical world. When the designers do not go beyond built environment, for example, when they only imitate physical forms/experience; Gu et al. define this approach of designers as metaphorical approach. Although use of place metaphor for virtual worlds is more crucial than decision for issues such as layout, virtual object design and navigation problem; Gu et al. (2007) proposed that in order to explore 3D virtual worlds from different perspectives, designers needed to go beyond built environment design and not to be too fixed on architectural design. Architectural design was not sufficient and the design could focus on interactions among people. This approach to designing 3D virtual worlds was defined as virtual approach and described as creating a place that only exists and makes sense in the virtual worlds (Gu et al., 2007). As a result, 3D virtual worlds began to respond to visitors reflectively, reactively or proactively (Smith et al. 2003), and both dynamic and modifiable virtual worlds began to be developed (Gu and Maher, 2005).

Furthermore, Maher and Simoff (2000) defined 3D designing as “Designing within the Design”, because of being represented by avatars in 3D world and avatars are immersed within the design. Thereby, 3D virtual worlds could support team collaboration, synchronous design communication (Gu et al., 2007), and design representation in addition to 3D modeling and computer programming/scripting.

Over the years together with the rising number of virtual worlds, Gu et al. (2007) introduced a new classification for design of virtual worlds; library-based design and

parametric design. Library-based design consists of a set of objects pre-defined outside the virtual world and provided by the virtual world object library. Modifying the objects in the library requires updates. Activeworlds design is an example for library-based design. Library-based designs might decrease creativity and in turn diversity of the virtual world fauna, because of using standard items. On the other side, parametric design consists of a set of objects determined within the virtual world. Parametric design allows selecting geometric types for objects and controlling their parameters. Second Life design is an example for parametric design Gu et al. (2007).

2.5 Human Computer Interaction - Usability

The designers of virtual worlds require more than designers of traditional two-dimensional interfaces. Design guidelines for traditional interfaces do not focus much on human performance; therefore, they do not guarantee meeting user expectations. However, virtual worlds require best user performance in order to deliver useful content and to succeed on specific objectives.

Throughout the past two decades, the relationship between the users and the design is explored within the field under different names such as User Centered Design, Man Machine Interface, Human Machine Interface, Operator Machine Interface, User Interface Design, Human Factors, Computer Human Interaction, or Human Computer Interaction. Generally, user interface design, also known as Human Computer Interaction, is relatively significant for virtual worlds (Bowman et al., 2002). Human-computer interaction (HCI) has emerged as a successful area due to its success in proposing solutions for problems in computing and due to being the visible part of computer science. Human-computer interaction is a science of design and often regarded as the intersection between behavioral sciences, and computer science and technology (Carroll, 1997). HCI researchers develop and evaluate new technology in order to understand users interacting with technology and support them through technology. They analyze and design specific user interface technologies. HCI has the goal of improving the usability of computer systems and applications of technology (Carroll, 1997).

Usability was introduced in the early 1980s to replace the term user-friendly (Bevan et al., 1991). And the term usability is firstly defined as “ease of use” by Miller (1971) and by Lazar and Preece (2002). Ease of use refers to the degree to which using a particular system is perceived to be free of effort (Davis, 1989; Venkatesh, 2000). After “ease of use” definition of usability, a discussion emerges that a system might be easy to use but at the same time it might be useless. Whether the user can achieve an intended goal via the designed system should be responded. Not only ease of use but also utility, reliability, and efficiency all respond to this question (Bevan, 1995b). And Shackel (1991) has given a formal definition for usability as “the capability in human functional terms to be used easily and effectively by the specified range of users, given specified training and user support, to fulfill the specified range of tasks, within the specified range of environmental scenarios”. The International Organization for Standardization (ISO) proposes two definitions of usability in ISO 9241 and ISO 9126. Supporting easiness and effectiveness, usability for a general product is defined in ISO 9241 as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” (ISO 9241-11, 1998). ISO 9126 defines usability narrowly as “the capability of the software product to be understood, learned, used and attractive to the user, when used under specified conditions” (ISO/IEC 9126, 2001).

Bennett (1984) developed a model of usability which consists of four major components: user, tool, task, and environment. He emphasized that usability depends on the interaction of users performing tasks through a tool in a specified environment. Therefore any intervention to one of these components could modify the whole interactions and in turn usability of the tool. Eason (1988) explained usability as “the degree to which users are able to use the system with the skills, knowledge, stereotypes and experience they can bring to bear”. Whiteside, Bennett, and Holzblatt (1988) defined usability broadly by stressing the real objectives of design. They consider users' experience as the ultimate test of system quality and focus on the existing links among usability, functionality and system architecture. Bevan et al. (1991) defined usability of a product as “a function of the particular user

or class of users being studied, the task they perform, and environment in which they work". In 1999, Dumas and Redish claimed that usability was observed when "the people who use the product can do so quickly and easily to accomplish their own tasks".

All of these definitions are gathered under three views (Bevan et al., 1991). First one is the product-oriented view which addresses that usability of a product is the ergonomic attributes of the product. Second one, the user-oriented view measures usability in terms of the mental effort and attitude of the user. Therefore, usability is strongly connected with the nature of the user. The definition of usability for software products by ISO above is an example for both product and user oriented view whereas the definition of usability for general products by ISO above is an example for only user-oriented view. And the user performance view is the third view of which Eason's definition (1988) is an example. It examines the interaction of the user with the product. This final view is also called as the quality of use view of usability (Bevan, 1995a). Usability is defined as the measure of the quality of the user's experience during the interaction with a product or system (Dumas & Redish, 1993; Guillemette, 1989; Nielsen 1993, 2000; Rosenbaum, 1989; Rubin, 1994). This view claims that usability is measured by the effectiveness, efficiency and satisfaction. This claim turns into that a system or a product should not only meet its specifications but also should be used in the real world, thus should be accepted by users (Bevan, 1995 b). Likewise, Holzinger defines usability as the quality of a system that makes it acceptable to users (2005) and attractiveness to users is stressed in the definition of Löwgren (2002).

ESPRIT (European Strategic Program on Research in Information Technology), which was a series of programs of IT research and development projects, offers a definition which includes all three of these views. ESPRIT conducted MUSIC project which developed metrics and tools for specifying and measuring the usability of interactive systems in the laboratory and the field (Macleod & Bevan, 1993). The current definition by ESPRIT is as follows " the ease of use and acceptability of a system or product for a particular class of users carrying out specific tasks in a

specific environment; where ‘ease of use’ affects user performance and satisfaction, and ‘acceptability’ affects whether or not the product is used” (Bevan et al., 1991).

Mack and Nielsen (1994) suggest another broad definition for usability as how easy it is for users to learn a system, how efficiently they can use it once they have learned it, and how pleasant it is to use. In addition, they point out the frequency and seriousness of user errors as parts of usability. Shackel (1986) puts four attributes forward as usability definition and evaluation criteria. These attributes are effectiveness, learnability, flexibility, and attitude. Effectiveness is measured with respect to the performance of a range of tasks such as the time to complete the task or the number of errors by some percentage of the users within some proportion of the environments in which the system will operate. Learnability is measured in terms of the time it takes for a user to learn to some specified level of competence after given a specific training. Flexibility covers the amount of variation in the tasks and/or environments which can be accommodated by the design. Attitude concerns the acceptable levels of human cost (tiredness, effort, discomfort, frustration etc.) which are required so that users are satisfied enough to continue to use and to enhance their use of the system (Benyon, 1993). Booth (1990) addresses two limitations of the Shackel’s definition. First limitation is the difficulty of flexibility to specify and communicate in a design environment and second limitation is the absence of an essential attribute of usability, usefulness (Booth, 1990). Booth defines usefulness as an attribute that helps users achieve their goals. Moreover, Booth mentions fulfilling the attributes of effectiveness, learnability, and attitudes is not sufficient. When the system functions fail to match a user’s work tasks, that system will not be used. Molich (1990), Yamada (1990), Hix and Hartson (1993), Shneiderman (1992) all offer similar usability attributes such as effectiveness, learnability, flexibility, utility, acceptability, memorability, likeability, attractiveness, operability, understandability, controllability, , installability, etc.

2.6 Usability Evaluation

Any system designed for people to use should be easy to learn and remember, effective, and pleasant to use. To what extend a system is usable. How a system’s

usability could be measured? Those are the main questions of designers ask. Over two decades researchers developed many methods to answer those questions. There are four ways of evaluating user interface of systems. First, automatically usability measures are computed by running a user interface specification by some program. Second, empirically usability measure is assessed by testing the interface with real users. Formally usability evaluation is using exact models and formulas to calculate usability measures. Lastly; informally evaluation is based on rules of thumb and the general skill and experience of the evaluators. Under the current circumstances it is not possible to use automatically evaluation and formally evaluation strategy is very hard to apply and is not being implemented well for large systems. Therefore it is better to emphasize on empirical and informal evaluation strategies.

According to study of Mack and Nielsen (1994) there are three dimensions of usability evaluation, effectiveness, efficiency and satisfaction. Mainly, effectiveness is whether the users of the system accomplish to given task or not, efficiency is error rate and time, while the users performing the given task and satisfaction is during those tasks the users how they feel themselves. Those three dimensions are measured by the following methods.

2.6.1 Heuristic evaluation

In this method, usability experts study the system thoroughly and look for familiar features according to their own experience and common sense. However, this may lead to a problem. A person using this method ideally should be using certain rules. The most commonly used rules are as follows: simple and natural dialogue, speak the user's language, minimize user memory load, be consistent, provide feedback, provide clearly marked exits provide shortcuts, good error messages and prevent errors (Nielsen & Molich, 1990). In this type of evaluation which representative users are not involved, results gathered from experts are combined and ranked to redesign each usability issue (Nielsen & Mack, 1994). Because this method is based on a set of heuristics, Nielsen (1994) emphasized that the expert evaluations are reliable only if the guidelines are reliable, too. One of the main difficulties of this method is that it uses usability experts as test users that restrict the population.

However, this method is fairly of low cost, does not waste users' time and requires only 3-5 experts and does not require advance planning (Galitz, 2002). According to Nielsen & Molich (1990), it could only be found 20 to 51 percent of usability issues in a system by using heuristic method.

2.6.2 Cognitive walkthroughs

Cognitive walkthrough is a method that evaluates a user interface based on each step that a user would perform and evaluates the interface's ability to support each step. This method aims to understand the usability of a design for first-time or infrequent users (Polson et al., 1992) and to assess a design for ease of learning by exploration (Wharton et al., 1994). This method allows to clear evaluation of the tasks during design process, prior to perform empirical user testing. Finding a design problem in early stages means it would be easy and cheap to fix it. Since the tasks are well defined it is less vulnerable to subjectivity and more structured than heuristic evaluation. On the other hand, it is tedious process and may not find inconsistency problems (Galitz, 2002).

2.6.3 Pluralistic walkthroughs

Pluralistic walkthroughs are meetings where users, developers, and human factors people meet together to discuss and evaluate step by step of a task scenario. As more people inspect the scenario for problems, the higher the probability to find problems. In addition, the more the interactions in the team, the faster the usability issues are resolved Bias (1994).

2.6.4 Formative evaluation

Formative evaluation is a method that evaluates user interaction by iteratively assigning representative users in task-based scenarios. This method is typically used for prototypes of a design. Informal formative evaluations provide qualitative results such as user comments and general reactions. On the other hand, formal formative

evaluations provide both quantitative results such as task timing, errors and qualitative results (Scriven, 1967; Hix & Hartson, 1993).

2.6.5 Post-hoc questionnaire

Post-hoc questionnaire includes a written set of questions which users are required to respond after they participate in a usability evaluation session. The questions seek for demographic information and diagnostic subjective data such as views and interests of users (Hix & Hartson, 1993).

2.6.6 Interview/demo

Interview/demo can gather more information about users than a mere questionnaire, since interview gives the opportunity to go into deeper level of information via direct speech. Subjective reactions, opinions, and insights can be acquired. Demonstrations of a design might be beneficial when a user is required to talk about the user interface (Hix & Hartson, 1993).

2.6.7 Summative or comparative evaluation

Evaluation compares statistically two or more configurations of user interface designs. This method is typically performed after a design is almost complete and after comparison, it aims to determine which design is better and cost effective (Hix and Gabbard, 2002). Evaluators gather both qualitative and quantitative data, while representative users are performing task scenarios (Scriven, 1967; Hix & Hartson, 1993).

2.6.8 Guidelines review

It is an inspection of an interface's navigation, screen design and layout in design guidelines of the system. A check list is prepared according to design document of the system and it is compared with the real system. In other words, this process is a control of whether design plans applied during the building process of the system.

Because developers can do this review, it is a low cost procedure. Moreover, general problems can be identified. However, due to the static nature of the test, it is possible to miss conceptual, navigation and operational problems (Galitz, 2002).

2.6.9 Think-Aloud evaluation

In this evaluation, while users are performing specific tasks, they are telling their thoughts. The main object here is to record user responses for analysis. This method gives valuable information why users do every step to accomplish the task (Galitz, 2002).

2.6.10 Focus groups

A focus group consists of a small group of knowledgeable users and a moderator. They discuss together proposed specific design tasks. It gives initial thoughts, has low cost and is easy to run. However, the group may not be aware of what kind of usability problems people using the system can have (Galitz, 2002).

2.6.11 User test

A user test evaluates a system under real world or controlled conditions. Target potential users perform specific tasks and measures of the performance are taken such as time and errors to complete tasks and number of users to test. Performance and attitudes of the users are examined. Those measurements are compared with previously defined goals and users' results (Galitz, 2002). Due to providing quantitative data, user testing is the most commonly used method.

2.7 Eye-tracking

Quantitative data required for usability evaluations can be gathered in various ways such as by using brain sensing technologies, software or questionnaires, or eye

trackers. Using eye tracking in Human Computer Interaction studies is a slowly developing but a promising method. There is a rise in eye tracking researches recently due to availability of cheaper, faster, more accurate, more mobile and easier to use eye trackers than in the past (Duchowski, 2003). Eye tracking is a technique that records eye movements and allows testers to determine eye-fixation patterns of a person (Namahn, 2001). Young and Sheena have a survey on eye tracking systems. The focus point of an observed person on a screen is called gaze point. Eye tracking allows the tester to capture the gaze of a person and to determine direction of gaze. It is based on measuring the fixations (dwell times) and saccades (fast movements) of these human gazes (Duchowski, 2007). Scan path is the resulting series of fixations and saccades. The direction of human gazes shows the focus of visual attention of a human. The tester can interpret what attracted the attention of the observed person from what s/he looked at in eye tracking technique (Duchowski, 2003). In other words, eye tracking is used for deducing cognitive processes resulting from the relationship between eye fixations and visual attention focus (Sennersten, 2008).

There are many techniques to implement an eye tracking system. Some might require special hardware, or wearing a device on user's head (Ohno et al., 2002), or might limit the user's head movements. A system attached to the user's head tracks eye-in-head direction, or a remote system tracks combined eye-head gaze direction in eye tracking (Weigle and Banks, 2008). When the system is head mounted, eye-in-head angles are measured; otherwise, gaze angles are measured.

Using an infrared lighting equipment (Ebisawa 1998), and highly specialized cameras, incorporating a well-trained neural network (Baluja and Pomerleau, 1994; Xu et al., 1998) are some of the common techniques. The techniques including neural network vary according to the way to capture the eye, the type of neural network, and the input to the neural network.

Eye tracking techniques are classified into two groups; intrusive techniques and non-intrusive techniques. Intrusive eye-tracking systems include physical contact between the sensor apparatus and the user; whereas non-intrusive systems do not include physical contact between user and sensor apparatus, generally benefit from cameras

(Weigle and Banks, 2008). Some examples for intrusive techniques might be measuring the reflection of infrared light onto the eye, measuring the electric potential of the skin around the eyes, or applying special contact lenses that facilitate eye gaze tracking (Glenstrup and Nielsen, 1995).

On the other side, incorporating one neural network (Baluja and Pomerleau, 1994), or two trained networks by using light into the user's eye, or employing neural networks without any special lighting on the user's face (Stiefelhagen et al., 1997) are examples for non-intrusive technique.

Non-intrusive camera-based eye trackers depend on unique properties of the eye from usual images. Figure 2.1 indicates some of the important anatomical features of the human eye. Limbus is the boundary between two different colors. Camera based eye tracking systems mostly benefit from two boundaries; pupil-iris and the iris-sclera. Iris-sclera which is called as limbus makes it difficult to track due to eyelids. The pupil-iris boundary has less contrast with respect to the limbus. Therefore, better contrast in pupil tracking systems required can be provided under infrared or near-infrared light source rather than under visible light. Invisible near-infrared light sources can be detected by many video cameras. When the light source is placed parallel with the camera, the camera sees the pupil as brighter than when the light source is placed nonparallel. Tracking in parallel position of the light source with the camera is called bright-pupil tracking and in nonparallel position is called dark-pupil tracking. Some eye tracking systems use both parallel and nonparallel sources with the camera in order to combine the two images of the eye to provide better contrast.

Purkinje images are multiple reflections of the light source in different layers of the eye. Purkinje images are listed as follows; first image is the reflection from the outer surface of the cornea, and the second image is the reflection from the inner surface of the cornea, and third and fourth images are produced at the surfaces of the lens. Commonly used image is called as corneal reflection which is the first one since it is easy to detect (Ebisawa et al., 1996; Morimoto et al., 2000; Hutchinson, 1989). The rest of the images require specialized equipment to be captured (Cornsweet and Crane, 1973; Crane and Steele, 1978).

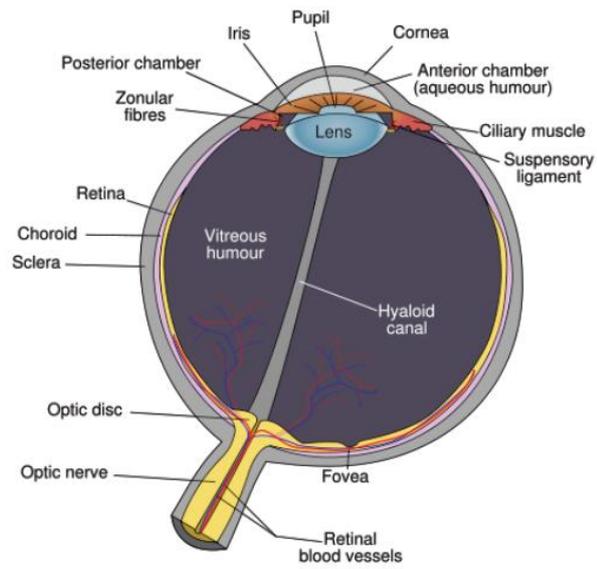


Figure 2.1 depicts anatomy of a human eye

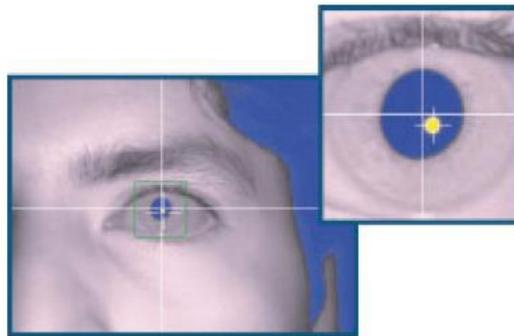


Figure 2.2 depicts the eye as seen by a camera

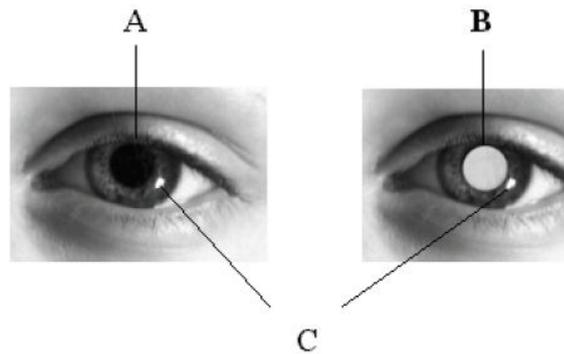


Figure 2.3 depicts the eye under each tracking modality.

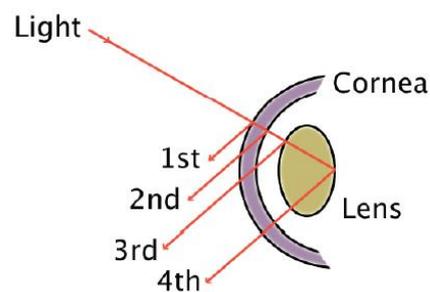


Figure 2.4 illustrates the anatomical sources of the first 4 Purkinje images.

Gaze direction of the eye and head position can be computed by using the relationship between the pupil and the corneal reflection in camera based eye tracking system. The vector between the pupil center and corneal reflection can be mapped to screen coordinates via a calibration procedure. The corneal reflection does track head movement, and the calibration will handle small head motions (Weigle and Banks, 2008).

Intrusive techniques give more accurate results than non-intrusive techniques, because in intrusive systems the sensor remains fixed with respect to the user's eyes whereas in non-intrusive systems user's head is mobilized and movements are not restricted (Morimoto and Mimica, 2005; Cornsweet and Crane, 1973). However,

intrusive techniques have the possibility to lead health damages more than non-intrusive techniques.

Eye tracking techniques are advantageous in that their use can be extended, and setting up is fast, and accurate and sufficient data can be attained, and they can tolerate small amounts of mobilization of head without invalidating the calibration (Poole and Ball, 2006; Rayner and Pollatsek, 1989; and Jacob and Kam, 2003). Camera-based trackers which are generally remote capture the images and aim to come through with the different features of the eye (Reulen et al., 1988 and Cornsweet & Crane, 1973). The amount of head movements that can be tolerated varies. Systems allowing only a few millimeters of head motion typically require a head restraint, e.g. a chin rest, be employed (Weigle and Banks, 2008).

2.7.1 Examples of eye-tracking studies

Primary eye-movement studies were approximately in the late 19th century (Jacob and Karn, 2003). Because primary eye-tracking techniques were involving direct mechanical contact with the cornea, they were invasive (Jacob and Karn, 2003). The first non-invasive technique belongs to Dodge and Cline (1901) which used light reflected from the cornea and recorded only horizontal eye position onto a falling photographic plate (Jacob and Karn, 2003). Nevertheless, their system was immobilizing the user's head. Judd, McAllister and Steel (1905) again inserted a material into the user's eyes in order to record the temporal aspects of eye movements in two dimensions by using motion picture photography. During the first half of the twentieth century, some researchers combined the corneal reflection and motion picture technique (Mackworth & Mackworth, 1958). Miles Tinker and his colleagues studied on the eye movements in reading by varying typeface, print size, page layout etc. in the 1930s (Tinker, 1963). In 1947, the eye movements of pilots while they were landing an airplane were studied via motion picture cameras by Fitts, Jones & Milton (1950). This study was the earliest application of eye tracking. First head-mounted eye-tracking system was invented by Hartridge and Thompson (1948) and developed by Shackel (1960) and Mackworth and Thomas (1962) in the 1960s. Mackworth and Thomas (1958) devised a system to record eye movements

superimposed on the changing visual scene viewed by the participant. In the 1970s, eye tracking data is linked to cognitive processes together with the developments and studies focused on how the eyes can display perceptual and cognitive processes (Jacob and Kahn, 2003). However, the number of studies in this area decreased after 1970s because too much effort was required for just data analysis other than data collection. Then, most researchers spent effort on solving the shortfalls with eye tracking technology and data analysis. Cornsweet and Crane (1973) focused on free movement of participants and discovered that multiple reflections from the eye could be used to separate eye rotations from head movement. US Air force/Honeywell Corporation and US Army/EG&G Corporation developed a remote eye tracking system after this discovery and decreased obtrusiveness of the participants and automated data analysis (Lambert, Monty & Hall, 1974; Monty, 1975; Merchant et al., 1974). When mini-computers were invented, an opportunity to process data at a high speed was found. Contrary to earlier eye tracking methods, this invention supported using data in real time as a means of Human Computer Interaction (Anliker, 1976).

Before 1970s, relationships between eye movements and simple visual stimulus properties such as target movement, contrast, and location were under consideration instead of relationships between eye movements and complex cognitive factors such as learning, memory, workload, and deployment of attention (Jacob and Karn, 2003). After 1970s, this changed and some models for relating eye fixations to specific cognitive processes were developed (Just & Carpenter, 1976). Because only scientific, educational, and engineering laboratories were including computers, eye tracking was not yet applied to the study of human-computer interaction at this point. Senders (2000) pointed out that each new eye tracking design to solve new problems has raised new problems for cognitive psychologists to tackle since the 1950s. Together with the increase in personal computers, researches about eye tracking applications for human-computer interaction appeared in the 1980s. While how users search for commands in computer menus (Card, 1984; Hendrickson, 1989; Altonen, Hyrskykari & Rähkä, 1998; Byrne et al., 1999) were being investigated, initially disabled users were focused (Hutchinson et al., 1989; Levine, 1981, Levine,

1984). In addition, work in flight simulators attempted to simulate a large, ultra-high resolution display by providing high resolution wherever the observer was fixating and lower resolution in the periphery (Tong & Fisher, 1984). Traditional user-computer communication combined with real-time eye tracking existed during the 1980s (Bolt, 1981, 1982; Glenn et al., 1986; Ware & Mikaelian, 1987).

When technology developed and evolved into new tools for information sharing such as the Internet, e-mail, and videoconferencing etc. in the 1990s, eye tracking for usability testing (Benel, Ottens & Horst, 1991; Ellis et al., 1998; Cowen, 2001) and for serving as a computer input device (Starker & Bolt, 1990; Vertegaal, 1999; Jacob, 1991; Zhai, Morimoto & Ihde, 1999) was required.

2.7.2 Eye-tracking and usability

Eye tracking in HCI typically investigates the scan path for usability purposes. Typically user studies rate human performance using measures such as time for task completion, participant success rate, type and number of errors and other subjective ratings such as ease of use (Nahamn, 2001). However, incorporation of eye tracking techniques in user studies can provide us with insights that would not be available from traditional user testing methods. The experimenter might require more knowledge of in which stimuli and for how long the user in the experiment might have looked at before making a decision (Karn et al., 2000). Eye-tracking can provide information about the pattern of fixations (scan paths), the time spent looking at various display components, and the deployment of visual attention (Nahamn, 2001). Knowing specifically what the user looked at could have a significant impact on the design of graphics algorithms and interactive techniques and reduce trial and error in user interaction design (Karn et al., 2000). Eye-tracking in usability assessment was used primarily for aircraft cockpit issues (Simmons, 1979). Although its use was expanded, Schnipke and Todd (2000) highlighted that it should be used in usability testing only if there is no alternative method for attaining the necessary data, due to budget and time limits of experimenters. However, all experimenters in Karn, Ellis and Juliano's study (2000) agreed that it was worth the time and effort to collect eye tracker data. Furthermore, response biases of

participants resulting from an artificial testing environment can be detected via eye-tracking, while they cannot be detected via traditional techniques. This would show the high validity of usability data collected by eye-tracking (Schiessl et al., 2003).

2.8 Brain-sensing technologies

Brain measurement in HCI has typically been used to investigate overall system difficulty where the user interface and task are viewed as one entity (Son et al., 2005; Izzetoğlu et al., 2004; Lee and Tan, 2006). However, UI designers generally want to minimize the workload required to work with UI, allowing the user to focus more workload on the primary task. Therefore, a high workload detected while a user works with a system is not necessarily a bad thing; it could indicate that the user is immersed in the task (Hirschfield et al., 2009).

There are innumerable techniques that are employed for brain imaging. Some focus on brain structure (e.g. Magnetic Resonance Imaging (MRI)), while others focus on the functionality of the brain (e.g. Magneto encephalography (MEG), Functional Magnetic Resonance Imaging (fMRI), Positron Emission Tomography (PET) and Single Photon Emission Computerized Tomography (SPECT)) (Martin, 2011).

2.8.1 Electroencephalography (EEG)

EEG is a test that measures the arousal dimension of human emotions and records the electrical activity of your brain using signals coming (Chanel et al., 2005). EEG requires the users to wear scalp electrodes which might usually be intrusive in order to measure and record the voltage between two electrodes on the scalp. Nonetheless, Nacke et al. claimed that users forget that they were wearing electrodes quickly (2008).

EEG makes measurements of brain waves which are described in terms of frequency bands (Oatley et al., 2006). The brain wave measures of brain activity can be linked to psychological structures (El-Nasr et al., 2011). Alpha band which is referred to as 8-13 Hz indicates a relaxed stage, where cognitive processes, arousal and attention

demand are limited (Pfurtscheller, Zalaudek, & Neuper, 1998; Ray & Cole, 1985). On the other hand, beta band of 14-30 Hz represents a state of attention and alertness, including cognitive and information processing (Ray & Cole, 1985). Theta activity which shows 4-7 Hz is related to creative processes, intuition, emotions and sensations (Aftanas & Golocheikine, 2001). Delta waves which constitute the part less than 4 Hz exist during deep sleep (Cacioppo et al., 2007), thus they are related to unconscious processes. Waves longer than 36 Hz are called as gamma-frequency, and are associated with the formation of percepts and memory (Miltner et al., 1999). However, the mechanisms and timing of temporal synchronization of brain activity with exact emotional responses are as yet not well known (Sander, Grandjean, & Scherer, 2005).

2.8.2 Positron Emission Tomography (PET):

Positron emission tomography (PET) is an imaging technique having medical or research aims, which produces a three-dimensional image of functional processes in the body. PET produces images of the body by detecting the radiation emitted from radioactive substances injected into the body. Having short decay time Carbon-11, Fluorine-18, Oxygen-15, or Nitrogen-13 could be example of such substances. To create short lived radioactive isotopes normal chemicals are bombarded with neutrons. PET detects the gamma rays that produced during collisions coming from the tissue.

Gama ray detectors arrays are gathered in a circular shape. The subject which injected with radioactive chemicals placed on a flat table which is the center of the detectors. During the collisions detectors produces electrical signals. These signals are processed by a computer to generate one image of the tissue. After that table is moved then whole this process is repeated again. Those generated images gathered to create 3D representation of the subject's organ such as brain, liver, etc. (Freudenrich, 2000).

However, PET has equipment of high cost and size as well as requirements on shielding, and a predilection to motion artifacts, making them difficult to utilize in

studies focusing on real-time active gameplay (El Nasr). Furthermore, the participants are required to absorb some amount of radioactive chemical in PET scan.

2.8.3 Single Photon Emission Computerized Tomography (SPECT)

The radioactive materials are used in SPECT technique in order to assess physiologic features of organs, or tissues; in this case of the state of brain. Multiple cameras capture multiple images and then, SPECT represents two dimensional or three dimensional images of radioactive material distribution in brain areas (Wernick, 2004). SPECT provides information about blood flow and the distribution of radioactive materials in the brain.

SPECT is a functional nuclear imaging technique introduced in the 1980s similar to PET. However, PET and SPECT differentiate in that the radioactive substances used in SPECT remain for a longer time than those used in PET. PET has more sensitive and more detailed images than SPECT, however SPECT is more affordable than PET (Freudenrich, 2000).

Because the humans are injected with a chemical that is radiolabeled, they are exposed to higher radiation in SPECT technique than other brain imaging techniques. And the long-term effects of SPECT on the human body are unknown today (Martin, 2011).

2.8.4 Magneto encephalography (MEG)

Magneto encephalography (MEG) is a non-invasive neurophysiological technique that measures brain function directly while other functional measures such as fMRI, PET and SPECT are measuring brain function reflecting brain metabolism. MEG records the magnetic fields that are generated by neuronal activity of the brain and passes unaffected through brain tissue and the skull unlike EEG. The magnetic fields are detected by sophisticated super-conducting sensors known as SQUIDS (superconducting quantum interference devices). When MEG signals were firstly measured in 1968 by Cohen, he was using a copper induction coil instead of SQUIDS

(Cohen, 1968). The locations of the neuronal sources within the brain are found by analyzing the magnetic fields and are superimposed on an MRI image. Thus, MEG combines functional information from magnetic field recordings with structural information from MRI and magnetic source images (MSI) are created.

MEG has higher temporal resolution than fMRI, PET, and SPECT. MEG can capture events of milliseconds. Furthermore, MEG has high precision due to millimeter resolution. The non-invasive feature of MEG is due to that it does not require any injection or exposure to X-rays or magnetic fields. As a result, children can be tested and also tests can be repeated (KIT/MIT MEG Joint Research Lab).

When more complex cognitive tasks are subject matter, MEG is used as complementary to fMRI to create functional maps of human cortex. Even, MEG can be also combined with other techniques than fMRI such as electroencephalography (EEG), and positron emission tomography (PET).

2.8.5 Functional Magnetic Resonance Imaging (fMRI)

Functional Magnetic Resonance Imaging (fMRI) refers to using magnetic resonance imaging (MRI) to detect the changes in blood flow and blood oxygenation in different brain locations that occur in response to neural activity. FMRI can show which parts of the brain are activated in a given task, process or emotion. How a part of brain is activated can be anticipated by more oxygen consumed and blood flow to that active part. Although it is not a direct measure, it is still explanatory for what is happening in the brain. Though its limitations, fMRI is more useful for detecting complex emotions because it provides a better spatial resolution than EEG (El Nasr). Moreover, fMRI can record signal from all regions of the brain, whereas EEG/MEG are biased towards the cortical surface of the brain and fMRI is high sensitivity to motion artifact.

Because fMRI does not involve ionizing radiation, it is non-invasive and it can be used repeatedly on a single subject and even on children. However, fMRI has equipments of high cost and size. Yet, the findings from fMRI can be integrated with

those from other techniques such as electroencephalography (EEG) and magneto encephalography (MEG), which inherently have higher temporal resolution (Savoy, 1996).

2.8.6 Functional Near-infrared Spectroscopy (fNIR)

As it was explained in earlier parts, fMRI had of large size and of high cost equipments in contrast with fNIR. FNIR is relatively inexpensive and portable for HCI researches (Hirshfield et al., 2009).

FNIR aims to find out active regions of the brain and functions by using near-infrared light. Near-infrared light is a specific light beyond the visible red light which is used to monitor hemodynamic changes. Near-infrared is in the range 800nm and 2500 nm wavelengths in the infrared band. FNIR is used to analyze hemodynamic changes due to cognitive and emotional brain activity (El Nasr, 2004) by focusing on specific areas of the brain which play critical roles in sustained attention, problem solving etc. (Cabeza & Nyberg, 2000). fNIRs are safe, non-invasive, and wireless (Bunce et al., 2006).

2.8.6.1 Principles of Functional Near-Infrared Spectroscopy

When the human brain is stimulated by environment, it undergoes a number of physiological changes such as change in blood levels and electrochemical activities which affect its optical properties. The change in optical properties of brain can be imaged by using light in the near-infrared range.

Increases in neural activity lead to an increase in glucose and oxygen consumption. When local glucose and oxygen decrease, the brain attempts to increase local arteriolar vasodilatation, which in turn increases local cerebral blood flow and cerebral blood volume. This period of increases is called as neurovascular coupling. In a several seconds, the increased cerebral blood flow carries glucose and oxygen to the area. The increased oxygen carried to the area result in an overabundance of cerebral blood oxygenation in active areas because it exceeds local oxygen utilization

(Fox et al., 1988). Although the initial increase in neural activity is thought to result in a focal increase in deoxygenated hemoglobin in the capillary bed as oxygen is withdrawn from the hemoglobin for use in the metabolism of glucose, this feature of the vascular response has been much more difficult to measure, and more controversial, than hyper oxygenation.

The change in the rate of oxygenated and deoxygenated hemoglobin can be measured via optical methods during neurovascular coupling due to their optical properties in the visible and near-infrared light range (Chance et al., 1998). Most biological tissues are relatively transparent to near-infrared light range. However, the chromophores oxygenated Hb and deoxygenated Hb absorb a fair amount of energy in these wavelengths, while water in the tissues absorbs very little. This range of wavelengths is referred to as the optical window (Jobsis, 1977). When the photons come across with the scalp, the tissues either scatter or absorb it. Photo detectors can measure these photons which form a banana shaped path while following a path from light source to scalp and back to light source. Beer–Lambert law states that absorption by oxy-Hb and deoxy-Hb varies linearly with the light path length and chromophore concentration. Beer–Lambert law is used to tell changes in light intensity measured on the scalp. Considering one wavelength more sensitive to oxy-Hb and the other to deoxy-Hb, changes in concentration of oxy-Hb and deoxy-Hb can be calculated. As a result, brain activity can be analyzed through the skull in adults (Chance et al., 1993). Not only hemoglobin, but also other chromophores can be assessed using similar optical technique.

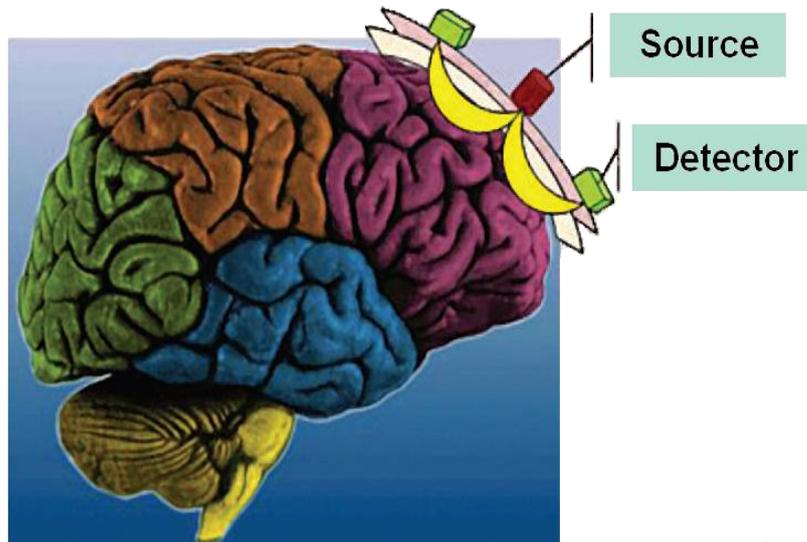


Figure 2.5 Banana shape

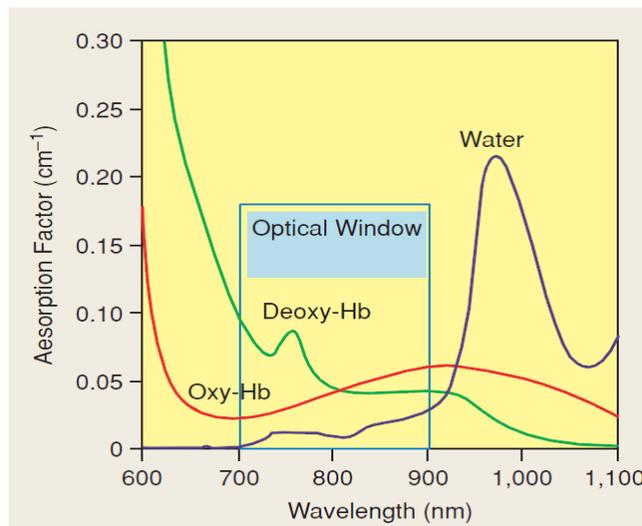


Figure 2.6 Optical window

FNIR equipment involves a head-mounted light source via either light-emitting diodes (LEDs) or through fiber-optical bundles and a light detector positioned 2-7 cm away from the optode. The light detector is required because light is scattered and it collects the light after light passes through the tissue. When there is a distance of 4 cm between the light source and light detector, the fNIR signal can sense

hemodynamic transformations within upper 2–3 mm of the cortex and extends laterally 1 cm to either side, perpendicular to the axis of source-detector spacing (Chance et al., 1988) Studies have shown that at interoptode distances as short as 2–2.5 cm, gray matter is part of the sample volume (Chance et al., 1988). Motor activity, visual activation, auditory stimulation, and the performance of cognitive tasks are some example activities of the brain which can be assessed via this technique (Villringer and Chance, 1997; Bunce et al., 2006).

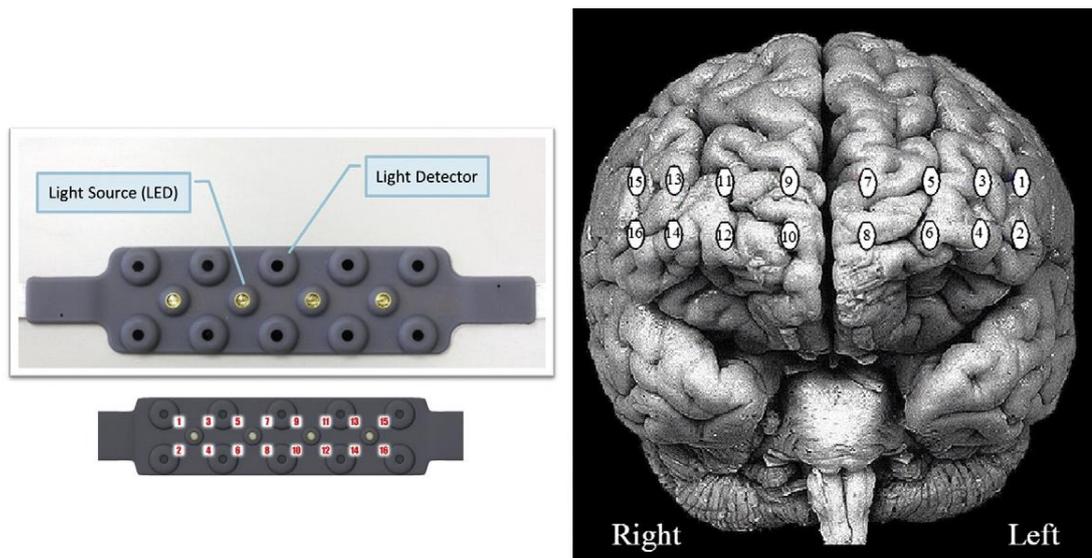


Figure 2.7 fNIR detectors (left) and its location on prefrontal cortex (right) Izzetoglu et. al

2.8.6.2 fNIRs System Types

fNIR instruments are used both as commercial and custom-built versions (Strangman et. al., 2002). fNIR systems are effective in terms of safety and cost. fNIR systems have three implementation types which are time-resolved systems, frequency- domain systems, and continuous wave spectroscopy systems. When changes occur in the phase and amplitude of the light, the more accurate information can be gathered via time resolved and frequency-domain systems due to more sophisticated detectors (Strangman et. al., 2002; Izzetoglu et. al., 2003). However, continuous wave (CW) systems provide capacity to design more compact and

inexpensive hardware, which results in usefulness for specified applications. Light-emitting diodes (LEDs) which decrease exposure of eyes to light can also be used in CW systems. Moreover, CW systems are both advantageous in terms of size and cost (Strangman et. al., 2002; Izzetoglu et. al., 2003).

2.8.6.3 Comparison of fNIRs with Other Neuroimaging Modalities

EEG and ERP measures are cost-effective, non-invasive, and have nearly instantaneous time resolution. As a result, they are advantageous for researches and contribute for developing models of cognitive and emotional processing. On the other hand, they can only provide an approximate location of an electrical source, instead of providing the accurate location. However, fMRI and PET gives opportunity to observe much more precisely the anatomical location of the neural circuitry underlying various mental events among human participants. Hereby, fMRI both provides safety and high spatial resolution. Therefore, comparing fNIR with fMRI would be meaningful. FMR is measuring brain activity due to changes in concentration of deoxy-Hb such indirectly as fNIR. Although both technologies have similarities such as safety and non-invasiveness, repeatedly implementation opportunity, they have many differences between. FMRI has better spatial resolution and is not limited with outer cortex while imaging such as fNIR. On the other side, fNIR is more advantageous for research studies under diversified conditions. FMRI requires participants lie and in turn, limits their movements. Moreover, fMRI can convert data into invalid with respect to any movement because of sensitivity. On the other hand, fNIR tolerates movements for participants and is quiet and comfortable more than fMRI. FMRI systems are relatively expensive due to their initial cost different from fNIR. FNIR systems also give opportunity to integration with other Technologies such as EEG.

2.9 Spatial Navigation Studies With fMRI And Mental Workload

Many researches have been made in the area of gender difference in spatial cognition (Gaulin, 1995). Although, many of them shows that males are outperform females in mental rotation and spatial navigation, females' performances are better than males

in spatial working memory (Levin, Mohamed & Platek, 2005). An fMRI study conducted by Levin et al. revealed that males outperformed females on the mental rotation task, but gender made no difference on the spatial working memory task. Males showed more activation in left parahippocampal gyrus, right medial frontal gyrus, inferior parietal lobe, and inferior frontal gyrus in the mental rotation task. Moreover, females showed activation in the left parahippocampal gyrus only. In Spatial working memory study females showed activation in left inferior frontal gyrus, while males activated left inferior parietal and medial frontal areas.

Ohnishi et al. worked on four groups of people (good navigator (male, female) and poor navigators (male, female)) in navigation. Ohnishi et al. used fMRI in their study and focused on hippocampus, parahippocampal gyrus, posterior cingulate cortex, precuneus, parietal association areas, and the visual association areas. Finally, they found that good navigators showed a stronger activation in the medial temporal area and precuneus than poor navigators. Moreover, they report that there was neither sex effect nor interaction effect between sex and navigation ability (Ohnishi et al., 2006).

Because of fMRI device was used during these studies, those areas even if are not in prefrontal cortex could be detected. Although fMRI has the capability to detect hemodynamic changes all parts of the brain, fNIR just detects those changes in Prefrontal cortex.

Gur et al., (2000) measured hemodynamic response to spatial tasks that varied in difficulty. They showed a proportional increase in hemodynamic response in the right parieto-occipital sulcus and left motor cortex as task difficulty increased.

There are plenty of fMRI studies related with working memory in the literature. These studies have shown that normal prefrontal activation tasks raise a number of areas in prefrontal cortex.

Goethals et al. (2003) state that functions within prefrontal cortex occur not only on prefrontal but also posterior brain areas.

The main areas which are activated during practice are prefrontal cortex (PFC), anterior cingulate cortex (ACC) and posterior parietal cortex (PPC) according to Kelly and Garavan (2004).

At least two different areas are responsible from Visual Working Memory which are prefrontal cortex (DLPFC) and the presupplementary motor area (pre-SMA). When the visual working memory limit is reached, these two areas can change their roles with each other Linden et. al. (2003).

For any moment, mental representations of a human are stored in visual short-term memory. Visual short-term memory (VSTM) is supported by different brain areas and has a limited capacity with which posterior parietal cortex activities are correlated. In other words, Todd and Marois (2004) point out that posterior parietal cortex is a significant location for mental representation of a visual environment.

2.10 Exploring Virtual Environments

The people gain the ability to view the virtual environment from different perspectives via visualization it provides. Egocentric and exocentric views are two of the perspectives that are used in exploring virtual environments. These two view types can be combined during exploration. In egocentric view, the user is embedded in virtual environment and s/he interacts from inside the environment whereas s/he interacts from outside in exocentric view (Wickens and P. Baker, 1995). Exocentric view is also called as the God's eye viewpoint such that flying above the environment can be given as an example (Wickens and P. Baker, 1995).

As a result of high visualization in virtual environments, Satalich (1995) introduces some questions which are related with navigational awareness such as "Is it possible or easy to recognize the current location in a large virtual environment or to determine the locations of other objects? (Satalich, 1995).

Satalich (1995) introduces navigational awareness regarding recognition of a virtual environment. Navigational awareness implies to possessing whole navigational

knowledge of an environment. (Satalich, 1995) Two distinct types of navigational knowledge are called *procedural knowledge* or *route knowledge* and *survey knowledge* (Satalich, 1995). Having both procedural knowledge and primary survey knowledge implies to having complete navigational awareness (Satalich, 1995). The sequence of steps that are needed to follow a particular path constitute procedural knowledge (Van Dijk, 2003). Procedural knowledge is gained via exploring a new environment (Satalich, 1995) The procedural knowledge is acquired via the navigator which directs the user to destination on a known route, but not presents alternative routes, such as short-cuts (Satalich, 1995).

On the other hand, survey knowledge is gained via exploring an environment using multiple paths (Satalich, 1995). Survey knowledge is characterized by the ability to take an exocentric viewpoint (Satalich, 1995). This is similar to construction of a cognitive map from many routes and landmarks (Goldin & Thorndyke,1982). A cognitive map is the mental representation of the environment which denotes the spatial knowledge (E. Tolman, 1948) or internal representation of the environment (Elvins 1997). Spatial knowledge is defined by the storage of acquired and processed information about transportation networks. Ramming (2002) It is considered as necessary for efficient way finding (Darken and Sibert 1996). Spatial orientation, *situational awareness*, and perception of elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future can be gained via cognitive map building (M. R. Endsley, 1988). Spatial orientation merely refers to being aware of current position and orientation whereas situational awareness refers to ability to make predictions in addition to spatial orientation. Situational awareness is defined as a person's momentary knowledge of the surroundings and his/her presence in it (Neerincx et al., 2000).

In order to acquire navigational knowledge in a new large-space environment, a constructive process has to be completed. Siegel & White (1975) explain this process with their "Sequential and Hierarchical" model. The first two steps within the process are necessary to build up procedural knowledge and the third and fifth to build up survey knowledge.

1. Landmark recognition: Lynch describes the reasons of recognizing objects as their distinctiveness and personal meaning (Lynch, 1960). The objects are distinctive due to their architectural style, their size, or color (Weisman, 1981). These visual attributes of the environment or static and perceptually prominent objects make up landmark knowledge (Thorndyke and Hayes-Roth 1982). The user perceives some landmarks as different and selects them as reference points (Vinson, 1999) to determine their position (Downs and Stea, 1973; Satalich, 1995).

2. Routes or Links: Routes and links are constructed during the travel between two landmarks. Moreover, images and landmarks are reminded in order to construct procedural knowledge.

3. “Primary” Survey knowledge: Primary experience implies to survey knowledge that is constructed by personal exploration (Presson & Hazelrigg, 1984).

4. “Secondary” Survey knowledge: Although secondary survey knowledge is not included in Siegel & White’s model, it will be discussed briefly. Only maps or pictures are used for gaining secondary survey knowledge about the environment (Goldin & Thorndyke, 1982; Thorndyke & Hayes-Roth, 1982). The users may be faulty in determining the locations or distances via survey knowledge. Moreover, underestimations may be conducted for curvy paths on the map (Wickens, 1991). Without having survey knowledge, it is required to spend high navigation effort (Edwards and Hand, 1997). Even if the users had not traveled earlier; inter-distances, locations, and landmarks could be known via survey knowledge (Satalich, 1995). Most of the researchers agree upon that the most significant requirement for successful navigation is survey knowledge (e.g. Darken & Sibert, 1996; Nash et al., 2000).

5. Chunking of the environment: When the environment is large, chunking the environment into smaller regions and nesting these smaller regions is required (Wilton & Pidcock, 1982) (Steven & Coupe, 1978). However, chunking of survey knowledge might end up with the situation in which participants only memorize locational knowledge, not the context around that location.

2.11 Navigation and Way finding

Navigation refers to the process by which people move using environmental cues and artificial aids in order to achieve a goal without getting lost and disorientation (Volbracht 1999, Darken & Sibert, 1993). In addition, Benyon & Höök (1997) classify navigation activities into three as goal-oriented aiming to reach a destination, explorative only looking around, and finally aiming at finding and identifying object. These three types of activities necessitate different types of navigation assistance (Van Dijk et. al., 1993).

Bowman et al. (2002) defines navigation in VEs as “moving the viewpoint within 3D space”. Navigation in virtual environments is critical because navigation is the most common interaction task for users and it is supportive of other tasks (Bowman et al., 2004). Navigation is not only a physical change of direction in an environment, but also a cognitive event. Navigation tasks consist of two main components: Way finding is the cognitive component of navigation, and travel or locomotion which refers to the movement/motion and motor component of navigation. (Bowman et al., 2004). Way finding is defined by Gluck (1990) as orientation and navigation process and by Golledge (1999) as the process of determining & following a ‘path’ or ‘route’ to successfully relocate from one location to another (Golledge 1999). Way finding is the ability of finding the path to a location conveniently and identifying the path when reached according to Peponis, et. al., (1990).

Krieg-Brückner et al., (1998); Werner et al. (2000); Spence (1999); Neerinx & Lindenberg (1999) make comparison of real world way finding with virtual world way finding. Van Dijk (2003) points out the less sensory details of virtual worlds than real world. When the participants disorientate, loss their way, or have difficulty in returning to a location visited before; they can get dissatisfied (Nash et al., 2000). Furthermore, complicated environmental structures may prevent users from developing cognitive maps (Raubal & Egenhofer, 1998). Darken and Sibert (1996) also state that users have difficulties in way finding in large virtual worlds because they have problems in constructing overall view of the space.

Downs and Stea (1973) and Satalich (1995) claimed that way finding is achieved in four steps;

1. Orientation: Finding out where the user is in respect to close objects and the destination.
2. Route Decision: Deciding about the route which will get the user to the destination.
3. Route Monitoring: Observing whether the user has selected the right route and is continuing on the right way.
4. Destination Recognition: Agreeing that the user arrived at the destination, or at least somewhere close to destination.

Chen and Stanney categorize this process into three primary parts: cognitive mapping, decision making, and decision execution. On the other side, according to Passini (2000); way finding consists of three main cognitive processes which are decision making and developing a plan, decision execution which is putting the plan into action, and finally perception and cognition. As a result of these cognitive processes, a mental model or cognitive map is constructed by the way finder (Chen & Stanney, 1999; Elvins, Nadeau, & Kirsch, 1999; Gommel, 1995; Murakoshi & Kawai, 2000). The users store environmental information in long term memory as a cognitive map.

2.11.1 Way finding affordances

An affordance implied to interactive properties that exist in an object or an environment according to Gibson (1950) who firstly developed the concept. On the other side, Zaff (1995) defines affordances as “measurable aspects of the environment but only to be measured in relation to the individual”.

When the virtual environments are taken into consideration, it is not easy to provide way finding in virtual environments since they do not include some cues and affordances such as in the real world (Elvins, 1997). As a solution, most researcher offer perceptual cues and affordances as efficient navigation aids for virtual environments.

Dondlinger and Lunce (2009) introduce six way finding affordances which are landmarks, topographical and spatial elements, depth cues, audio cues, and avatar perspective that designers have to consider when constructing VEs for instruction. However, way finding affordances are not limited with these six today. In addition, there exist some other researchers that claim way finding techniques that are learned in real world can also be used to navigate in VEs (Darken & Sibert, 1996; Murray, Bowers, West, Pettifer, & Gibson, 2000; Passini, 2000; Vinson, 1999).

As signs, auditory affordances, agents, and maps are used in this study; the focus point from now on will be gathered among these affordances.

2.11.1.1 Signboards:

Signs or signboards are considered as common way finding affordances for both real world and virtual environments by most of the researchers and have been ignored. Butler et al. (1993) discovered in their research that while the participants who benefited from signs completed tasks in the same time period with the ones who benefited from no navigational aid; the participants who benefited from maps completed tasks in longer time period than all participants.

2.11.1.2 Agents:

Chittaro et al. (2004) introduced embodied agents as way finding affordance. Agents serve as navigation and information aids. They are navigation aids because they are assistants for the users in finding target location or object. Also, they are information aids because they inform the users when they face with a new location or object. Chittaro et al. (2004) also point out the attractiveness and immersiveness of agents in 3D virtual environments. Nijholt & Hulstijn (2000) focuses on the believability of agents sourced from their improvement.

As it is stated before, the users of virtual environments may get frustrated; fail to see significant parts of especially large environments (Chittaro et al. 2004). Then, navigational aids are required by especially for novice users. In the research of

Chittaro et al. (2004), human-like agents provide guidances via a tour in a 3D virtual museum. Chittaro et al. (2004) introduced automatic code generation for communication with agents. These agents invite the user into tour and gives information continuously. The users are also free to visit the environment without following the tour. Ennis and Mayer (2001) claim that a large number of users explore the virtual environment at the greatest level in these kind of guided tours. In addition, some of the experienced users ignore the tour and continue exploration, while novice users benefit from this type of navigational aid.

Van Dijk et al. (2003) classifies agents based on three different criteria as pro-active or reactive, embodied or not, and dynamic or not. In the project of Van Dijk et al. (2003), two personal agents were used, one is an embodied information agent which is reactively responding questions of the users and the other one is personal agent which is dynamic and pro-actively giving information specific to the user. However in their project both maps and landmarks together with agents are used. When the user types a question, the system points the target location on the map route that the user is asking.

Rickel and Lewis Johnson (2000) emphasize the auxiliary and attractive feature of embodied agents due to their pointing gestures, body orientation and gazes. Rickel and Lewis Johnson (2000) imply that it is more effective to point the location of the target than to describe the location. Furthermore, some researchers attract attention to motivational effect of embodied agents in dead like environments when the users feel lonely (Lester et al. 1997; van Mulken et al. 1998).

2.11.1.3 Auditory Affordances:

Musical sounds used mostly consisted of non-continuous musical sounds (Walker and Lindsay 2003; Lokki et al. 2000) in the literature. Dodiya and Alexandrov (2008) presented continuous musical sound as a navigation aid. They point out another aspect of auditory affordances. Both sighted and visually impaired users would benefit from speech audio. In addition, non-speech audio gives continuous data to the users.

The two dimensional environments where including auditory navigation techniques which used musical sounds with auditory icons (Dodiya and Alexandrov 2007). However, for 3D environments, auditory affordances were not investigated in detail. Non-speech sounds for navigation have been investigated by many researchers such as Walker and Lindsay (2003), Lokki et al. (2000), and Constabile et al. (2003).

Dodiya and Alexandrov (2008) claim that continuous music in virtual environments keeps immersion and engagement of the users. In addition, music is a universal language so that no language barriers remain for all users. As Begault (2000) explains about auditory localization instinctive in humans which allows the users to choose the path in accordance with the audio source. Dodiya and Alexandrov (2008) also used music stop as an end of the task when the user achieved the goal of the task in their research.

Chittaro et al. (2004) used auditory cues in their research such as sounds of objects and human actions to add realism. Noise and sounds in the environment not only make the users feel immersed but also enhance their focus of the attention Chittaro et al. (2004).

2.11.1.4 Maps

Maps as way finding affordances require the user to continuously switch between egocentric and exocentric views as a result; Chittaro and Burigat, 2004 claim that maps require high mental effort. On the other hand, Satalich (1995) claims that when the users acquire a map before interaction with the virtual environment, their performance improves. Edwards and Hand (1997) also emphasize the ability of maps in providing survey knowledge.

Maps in virtual environments can be shown as a separate GUI next to or on top of a 3D world which calls as detached affordance cues (Barfield et al., 1995), or as an inclusive element of the 3D environment which calls as embedded affordance cues.

Detached maps are considered as a real part of the environment and they enable active searching of information which results in active exploration of the environment (Adams, 2006). The users can benefit from detached affordance cues whenever they need (Bowman et al., 2004). Still, the users have to make shifts between two different GUI modes (Bowman et al., 2004). Moreover, these maps cover great part of the display which in turn hinders that part of the environment (Bowman et al., 2004). Whereas embedded maps do not hinder the environment or restrain the visual area of the users. However, because these embedded affordance cues are not always visible, users must memorize the location of maps and move to them, when they need, which then may decrease effectiveness.

Choi (2011) conducted a research which four different way finding affordance conditions are implemented for participants. These conditions are specified by Choi in terms of visibility of cues as fixed and movable and in terms of location of cues as fixed and movable. According to Choi's research, both being experienced of the user and also being detached of maps influence better task performance. In addition, the users feel more presence and satisfaction in environments with fixed and detached maps. And the users are least satisfied and have difficulty in achieving tasks in virtual environments with embedded maps due to the need to memorize next destinations and routes. However, they consider environments with embedded maps as more appealing and similar to the real world.

Thorndyke and Hayes-Roth (1982) and Goldin and Thorndyke (1982) claim that maps alone do not provide navigational awareness. Thorndyke and Hayes-Roth(1984), found no difference between the map-study groups and control groups when they made comparisons between the participants who are experienced without seeing any map and participants who are not experienced but have seen a map of the environment. In addition, the participants who are experienced in the environment performed better than the map-study participants in finding Euclidean distances. Thus, Thorndyke and Hayes-Roth(1984) do not favor secondary survey knowledge.

1985 Streeter, Vitello and Wonsiewicz performed a way finding study comparing navigational aids for people driving in a car. This study showed that while way finding it is more difficult to interpret a map than it is to receive directions.

Darken and Sibert, 1996 support electronic maps for the virtual environment users during way finding. Chittaro et al. (2004), however, highlight that maps require much effort to interpret because the users have to construct egocentric perspective from exocentric perspective.

In conclusion, the signs and verbal directions are supported rather than maps by most of the researchers.

2.12.1 Design Principles for Wayfinding

These principles aim to make environments effectively navigable. Navigability is described as that the navigator can successfully move the participant in the environment to a destination. The navigability of an environment depends on three criteria. First criterion is the recovery ability of present location and orientation of the participant. Second criterion is the ability to fulfill wayfinding task successfully. And third criterion for navigability is the ability of the navigator in accumulating wayfinding experience and form a mental image or map of the environment.

2.13 Summary of Literature

Bell combined these two prior definitions as “A synchronous, persistent network of people, represented as avatars, facilitated by networked computers” (Bell, 2008). Nearly all virtual worlds give opportunity for many real life activities such as shopping, chatting, creating art works etc. The virtual worlds should be utilized because they are cheap, accessible, and not dangerous and not time consuming. In addition to growing virtual worlds, some example large virtual worlds are namely, Onverse, Kaneva, Twinity, Activeworlds, and finally Second Life which is within the scope of this study. Arts, educational and science activities are some examples for activities that can be performed within a virtual environment. A virtual campus, a

type of educational virtual world, can be defined as an environment that represents a university and provides users with a special place and a set of tools for learning (Fominkyh et al., 2008). Although different universities use different platforms, extensively used platform today for virtual campuses is Second Life. In fact, the virtual worlds offer more than security and cheapness; also they provide augmented capabilities such as flying and augmented realities such as expanding time which are not possible in real world.

The designers of virtual worlds require more than designers of traditional two-dimensional interfaces. Design guidelines for traditional interfaces do not focus much on human performance, therefore they do not guarantee meeting user expectations. However, virtual worlds require best user performance in order to deliver useful content and to succeed on specific objectives. Thereby, Human Computer Interaction emerged as the intersection between behavioral sciences, and computer science and technology (Carrol, 1997). HCI has the goal of improving the usability of computer systems and applications of technology (Carroll, 1997).

Although too many definitions for usability exist, Shackel (1991) has given a formal definition for usability as “the capability in human functional terms to be used easily and effectively by the specified range of users, given specified training and user support, to fulfill the specified range of tasks, within the specified range of environmental scenarios”. Usability is measured by the effectiveness, efficiency and satisfaction.

There are four ways of evaluating user interface of systems. First, automatically usability measures are computed by running a user interface specification by some program. Second, empirically usability measure is assessed by testing the interface with real users. Formally usability evaluation is using exact models and formulas to calculate usability measures. Lastly; informally evaluation is based on rules of thumb and the general skill and experience of the evaluators.

According to study of Mack and Nielsen (1994) there are three dimensions of usability evaluation, effectiveness, efficiency and satisfaction. Mainly, effectiveness

is whether the users of the system accomplish to given task or not, efficiency is error rate and time, while the users performing the given task and satisfaction is during those tasks the users how they feel themselves. Those three dimensions are measured by the different methods such as heuristic evaluation, cognitive walkthrough, pluralistic walkthrough, formative evaluation, post-hoc questionnaire, interview/demo, summative or comparative evaluation, guideline reviews, think-aloud evaluation, focus groups, and user tests.

Brain sensing technology and eye tracking are the two of ways for gathering quantitative data required for usability evaluations. Incorporation of eye tracking techniques in user studies can provide us with insights that would not be available from traditional user testing methods. Eye tracking is a technique that records eye movements and allows testers to determine direction of gaze of a person (Namahn, 2001). The direction of human gazes shows the focus of visual attention of a human. The tester can interpret what attracted the attention of the observed person from what s/he looked at in eye tracking technique (Duchowski, 2003). Thus, eye tracking can be used for interpreting cognitive processes (Sennersten, 2008). Eye tracking techniques are classified into two groups; intrusive techniques including physical contact and non-intrusive techniques not including. In the past, intrusive techniques were used commonly and the participants could not feel comfortable. Cornsweet and Crane (1973) focused on free movement of participants. After 1970s, some models for relating eye fixations to specific cognitive processes were developed (Just & Carpenter, 1976).

When brain sensing Technologies are considered, there are numerous methods such as Electroencephalography, Positron Emission Tomography, Single Photon Emission Computerized Tomography, Magneto encephalography, Functional Magnetic Resonance Imaging, and finally fNIR. FNIR is a technique that aims to find out active regions of the brain and functions by using near-infrared light. Hemodynamic changes due to cognitive and emotional brain activity can be analyzed by fNIR (El Nasr, 2004).

There exist researches related with the participants navigating in an environment in which usability evaluation is performed. Satalich (1995) introduces navigational awareness regarding recognition of a virtual environment. Navigational awareness implies to possessing whole navigational knowledge of an environment (Satalich, 1995). In order to acquire navigational knowledge in a new large-space environment, a constructive process has to be completed. Siegel & White (1975) explain this process with their “Sequential and Hierarchical” model which consist of landmark recognition, routes, primary survey knowledge, secondary survey knowledge, and chunking of the environment. Navigation refers to the process by which people move using environmental cues and artificial aids in order to achieve a goal without getting lost and disorientation (Volbracht 1999, Darken & Sibert, 1993). Dondlinger and Lunce (2009) introduce six way finding affordances for assisting the participants in an environment which are landmarks, topographical and spatial elements, depth cues, audio cues, and avatar perspective. In addition there are some other researchers such as Butler et al. (1993) focusing on signboards, Chittaro et al. (2004) and Nijholt & Hulstijn (2000) on agents, Dodiya and Alexandrov (2008) and Begault (2000) on auditory affordances, Satalich (1995) and Bowman et al. (2004) on maps.

CHAPTER 3

METHODOLOGY

This research aims to explore effects of different types of navigation way finding cues on users' satisfaction, performance, and mental workload. Information about research questions, variables, instruments, apparatus, software, treatments, task scenario, pilot studies, pilot study findings and solutions, experiment setting, data collection, experiment groups, data analysis methods are provided in detail throughout this chapter.

3.1 Research Questions:

Throughout this study following questions will be investigated:

What are the effects of way finding affordances, including voice, map, agent, and sign on usability?

What are the effects of way finding affordances, including voice, map, agent, and sign on users' performance in terms of task completion time and length?

What are the effects of way finding affordance, including voice, map, agent, and sign on users' satisfaction?

What are the effects of way finding affordance, including voice, map, agent, and sign on users' mental workload?

3.2 Variables

Dependent Variables: There are eleven dependent variables in this study.

Task completion time (TCT): Duration between participants' starting the task and completion in terms of time.

Total task completion time (TTCT): There nine tasks in the environment. Total task completion time was calculated by adding up each of task's completion time in terms of seconds.

Task completion length (TCL): The distance between the participants' starting point and completion point on the map in terms of centimeters.

Total task completion length (TTCL): There nine tasks in the environment. Total task completion length was calculated by adding up each of task's completion length in terms of centimeter. Each participant's every task path drawn on a bird eye view of the METU virtual campus then same paths are drawn a graphic design program which name is InkScape then total path length calculated by the program.

Total task completion accuracy (TTA): Total task completion accuracy is a percentage value of how many of nine tasks were completed successfully by the participants.

User satisfaction (US): User satisfaction is evaluated by System Usability Scale (SUS). The calculation of the score is explained in detail in instruments section.

Mental work load (MWL): It is the oxygenation level evaluated by fNIR device. fNIR results were evaluated by voxel number. V6AVG means average oxygenation level evaluated by voxel-6. Also, V6T1 means average oxygenation level during task-1 evaluated by voxel-6. Throughout this study following dependent

variables were used as representation of mental workload, Left Hemisphere Average LHA, RHA, V6AVG, V16AVG, V6T1 to 9, V16T-1 to 9.

Standard Signboard Gaze Duration (SSGD): Users gaze duration on standard signboards for each task in terms of seconds.

Total Standard Signboard Gaze Duration (TSSGD): Sum of users gaze duration on standard signboards for all tasks in terms of seconds.

Navigation Cue Gaze Duration (NCGD): Users gaze duration on navigation cues (maps, signboards, voice kiosk and agents) for each task in terms of seconds.

Total Navigation Cue Gaze Duration (TNCGD): Sum of users gaze duration on navigation cues (maps, signboards, voice kiosk and agents) for all task in terms of seconds.

3.3. Instruments, Apparatus and Software.

In this study two questionnaire, one of which user information before the experiment and System Usability Scale after the experiment, an observation form, an after the experiment interview questionnaire, fNIR and Tobii-t120 were used. In the following sections these instruments and equipment will be explained in detail.

User information questionnaire was used for getting each prospective participant's information and present descriptive statistics about them before the experiment. It can be seen in Appendix-C.

Observation form was used for taking notes about the participant's performance during the experiment. For instance, the participant's attitudes during task-1, whether s/he complete the task successfully. It can be seen in Appendix-E.

3.3.1 System Usability Scale (SUS)

System Usability Scale (SUS) is a tool developed by John Brooke in 1986 for evaluating systems or products usability quickly, accurate and cheap. SUS has 10 likert type questions. Questions scale is between 1 and 5. SUS provides a usability score between 0 to 100, 0 means the system's usability is not good and 100 means its usability is very good. Calculation of SUS score is done as follows: 1 point subtracted from 1,3,5,7,9 numbered questions' score and 2,4,6,8,10 numbered questions score is subtracted from 5. Then, all questions scores are added each other then multiplied by 2,5.

In order to translate SUS from English to Turkish correctly the researcher applied cross translation procedure. Five different peers translate original SUS document from English to Turkish. The researcher gathered all these documents and combined them as one. Then, two English teachers translated this document from Turkish to English. At the end the original SUS and translated SUS document compared by a teacher whose occupation translation English to Turkish, Turkish to English and it was seen both document almost identical. After that, the word of system was replaced by environment by the researcher. Translated SUS questionnaire can be seen in Appendix-D and the original SUS document can be seen in Appendix-D.

Five interview questions were asked each participant who completes the experiment except one participant who felt nausea in the beginning of the experiment. The goal of the interview was to learn participant's opinions about the environment since it was asked them not to talk as possible as they can during the experiment in order to keep fNIR data from distortion. Interview questions can be seen in Appendix-F.

3.3.2 Second Life METU Island:

Second life was chosen to build METU virtual campus. In virtual campus consists of three different areas group working area, media center and faculties and departments. Group working area has two group working towers, one social area, one dancing area, one group meeting area, one amphitheatre and two virtual classrooms. Media

center has one photograph and video gallery, one cafe and a one disco. Faculties and departments area consists of one convention center, five faculties and thirty eight departments. Second life viewer 3.1.4 version was used for during this study.



Figure 3.1. Bird eye view of the METU virtual campus

- | | |
|-------------------------|---------------------------------------|
| 1. Group Working Towers | 11. Disco |
| 2. Social Area | 12. Faculty of Architecture |
| 3. Dancing Area | 13. Faculty of Education |
| 4. Amphitheatre | 14. Faculty of Education Amphitheatre |
| 5. Group Meeting Areas | 15. Faculty of Engineering |
| 6. Virtual Classroom-1 | 16. Faculty of Arts and Sciences |

7. Virtual Classroom-2

8. Media Center

9. Video Gallery

10. Cafe

17. Faculty of Arts and Sciences Amphitheatre

18. Faculty of Economic and Administrative Sciences

19. Convention Center



Figure 3.2 Profile view of METU virtual campus



Figure 3.3 METU Virtual Campus view from center of the campus

3.3.3 Tobii T 120

Tobii T 120 will be used as an eye tracking device. Tobii T 120 collects data of where the user looks on the screen, how long the glance are, how many times the user looks at certain points on the screen, and all of the eye movements of the subject during the experiment. It attached to a 17 “ flat LCD screen. Tobii T 120 could capture the user’s glance of a 0.5 degree of accuracy 120 frame in a second. Users are free to move his/her head 30 cm on horizontal axis, 22 cm vertical axis also 30 cm backward or forward to the screen. Moreover, Tobii T120 can track user’s both eyes. It also has a built in camera to record user’s face during test.

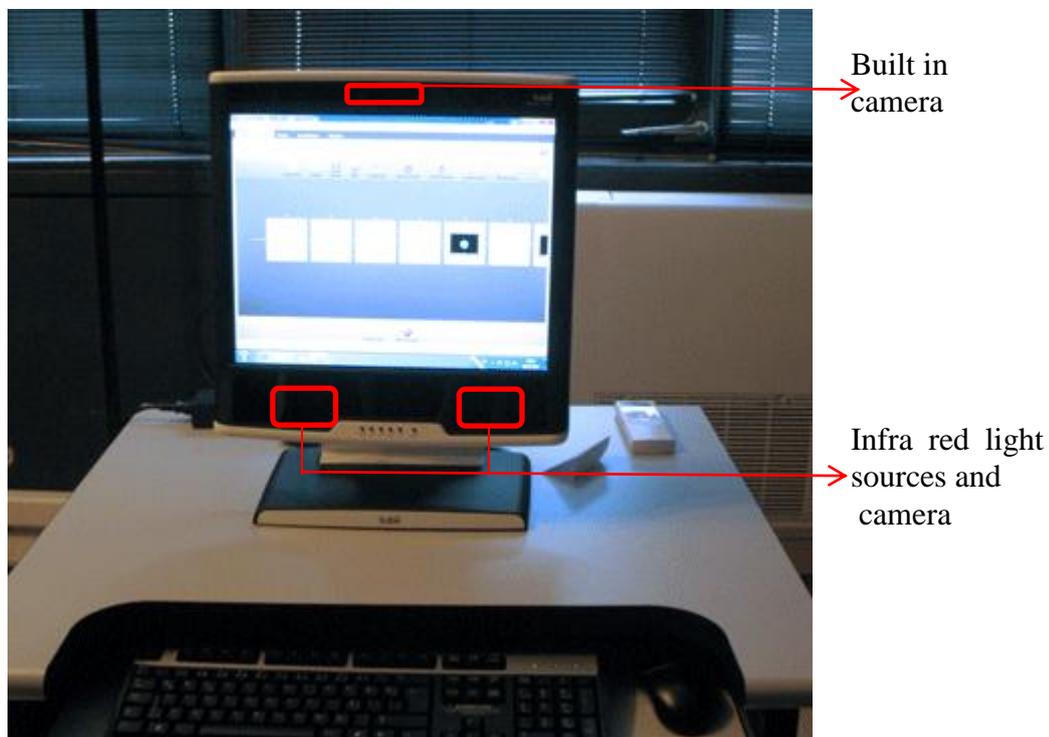


Figure 3.4 Tobii T 120

The recorded raw data of eye tracker has to be processed in order to get meaningful information. This process is done by software which is called Tobii Studio. Tobii Studio is developed by the manufacturers of the eye tracker. It transforms the data which are received from the reflectors and the infrared detector cameras into visual

and digital data, records them and later provides various tools for analyzing the data saved. Tobii studio 2.2.4 version was used for this study.

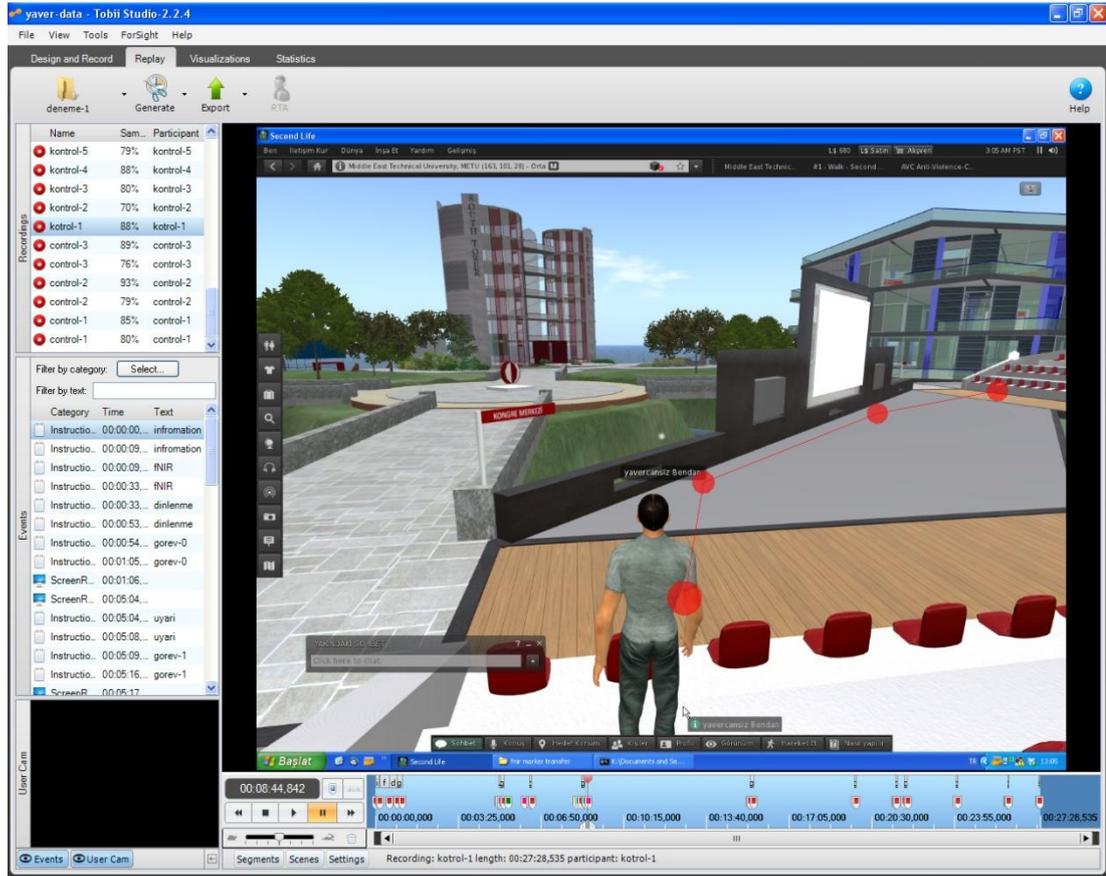


Figure 3.5 Tobii.2.2.4 interface

3.3.4 Functional Near Infrared (fNIR) spectroscopy

When the human brain is stimulated by environment, it undergoes a number of physiological changes such as change in blood levels and electrochemical activities which affect its optical properties (Bunce et al., 2006). The change in the rate of oxygenated and deoxygenated hemoglobin can be measured via optical methods. fNIR device measures these changes which take place in preferential cortex. In this study fNIR Imager 1000 which is a continuous wave NIR spectroscopy will be used.

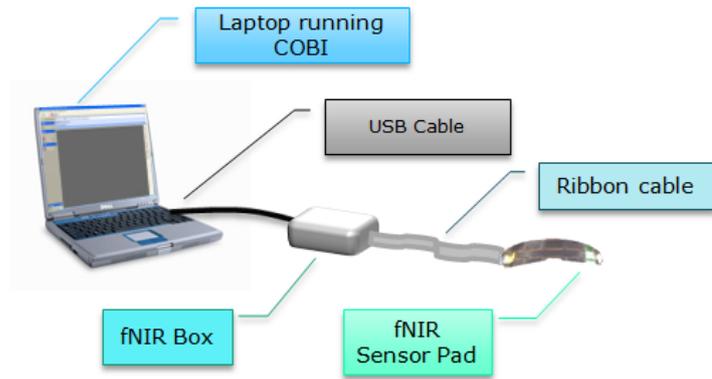


Figure 3.6 fNIR experiment setup

fNIR Sensor Pad:

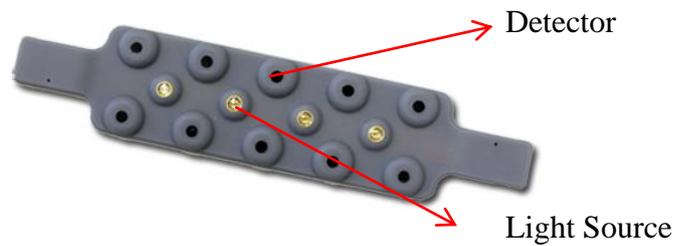


Figure 3.7 Sensor head band

Sensor pad consists of four near infrared light source and ten detectors. It is attached to control unit via 2x15 cm cables with 14 pin connectors. Mounting the sensor pad correctly is the most important step of the getting fine data. Depending of the user's hair length, a hair band could be used.



Figure 3.8 Mounted sensor pad and fNIR control box

Cognitive Optical Brain Imaging Studio (COBI) is a hardware integrated software platform that enables users to acquire, process and visualize fNIR signals (manual).

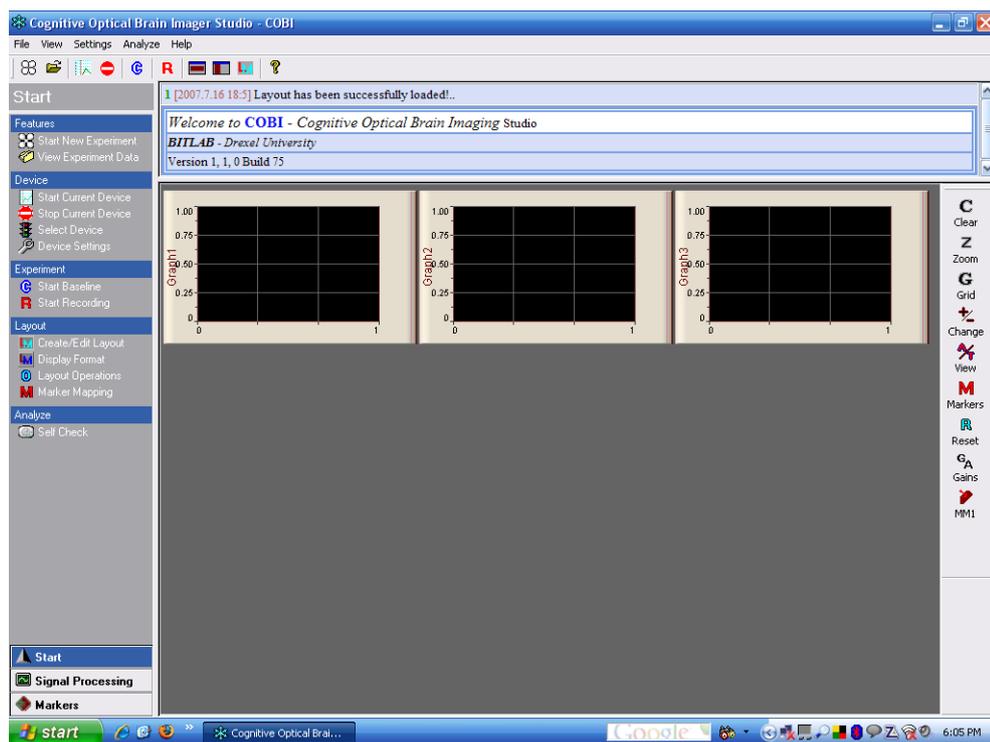


Figure 3.9 COBI software interface

3.4 Treatments

In this experiment setting there were four treatments groups control group, map group, sign group, voice group and agent group. Each treatment group will be explained detail in following sections.

3.4.1 Control group

In order to compare different treatments' results a control treatment was established. The results of control group provide a base line for comparison between different treatment effects. In control treatment, a sign placed in front of the all buildings and areas that present information about the areas or what facilities are located in in the building. The goal of placing these signs is to inform the participants where they are or which building they are in. These signs remain in all other treatments to keep them as standard. The location of signs can be seen in the following picture.

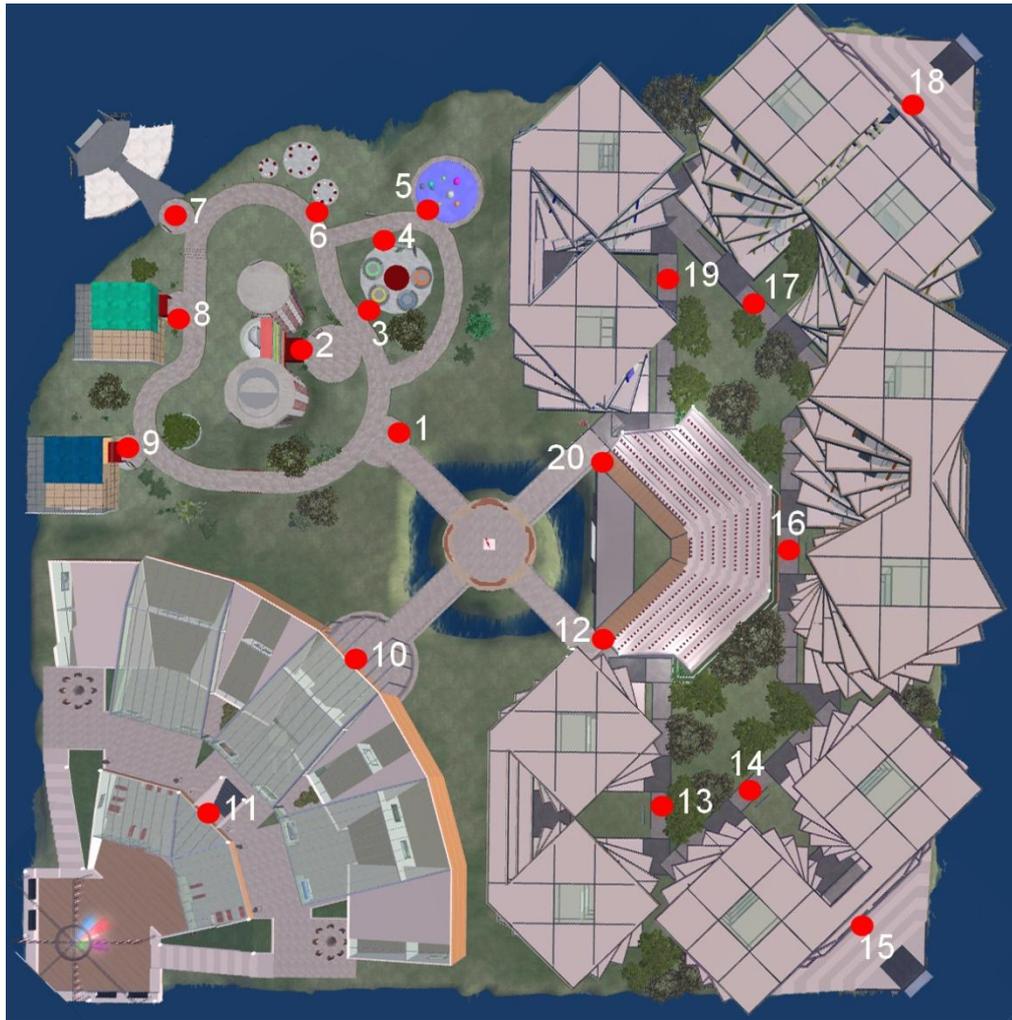


Figure 3.10 Bird eye view of locations of signs in control treatment

Also it can be seen number 12 sign as an example in Figure 3.11.



Figure 3.11. Standard signboard.

3.4.2 Map group

In map treatment, a sign placed in front of the all buildings and areas that present information about the areas or what facilities are located in in the building as control treatment. In addition, a map is provided in 14 different locations of the environment. The goal of placing these maps is to help participant to reach their destinations by providing information of where they are and how they can reach there. The provided maps can be divided in two parts in first part there is a list of areas and buildings located in the METU virtual campus and the other part is a bird eye view of the campus each area and building has a number. The participant could reach the name and location of the destination by searching the number of the building or area in the list. Also, there is a red point in the map representing the location of the participant. The location of maps and a sample map can be seen in the following pictures.



Figure 3.12 Maps location in the METU virtual campus



Figure 3.13 Sample map



Figure 3.14 A map placed in METU virtual campus

3.4.3 Signboard group

In sign treatment, a sign placed in front of the all buildings and areas that present information about the areas or what facilities are located in in the building as control treatment. In addition, signs are provided in 19 different locations in the environment. The goal of placing these signs is to help participant to reach their destinations. The location of signs and a sample sign can be seen in the following pictures.



Figure 3.15 Sign locations in METU virtual campus



Figure 3.16 A sign placed in METU virtual campus

3.4.4 Voice group

In voice treatment, a sign placed in front of the all buildings and areas that present information about the areas or what facilities are located in in the building as control treatment. In addition, voice kiosks are provided in 27 different locations in the environment. The goal of placing these voice kiosks is to help participants to reach their destinations. When the participants come near by the kiosk, it starts to play a sound that describes which facilities or areas behind it. The participants were able to know what buildings or areas located in that direction without going there. The location of voice kiosks and a sample kiosk in the environment can be seen in the following pictures.



Figure 3.17 Voice kiosks' location in METU virtual campus



Figure 3.18 A voice kiosk in METU virtual campus

3.4.5 Agent group

In agent treatment, a sign placed in front of the all buildings and areas that present information about the areas or what facilities are located in in the building as control treatment. In addition, agents are provided in 7 different locations in the environment. The goal of placing these agents is to help participant to reach their destinations. When the participants comes near by agents and type via chat tool the task number or tell the task number via microphone to the agent, it describe the destination via chat tool and shows the direction by walking few steps to it. The participants were able to know what buildings or areas located in that exact direction without going different places. The location of agents and a sample agent in the environment can be seen in the following pictures.



Figure 3.19 Agent locations in METU virtual campus



Figure 3.20 An agent in METU virtual campus

3.4 Task Scenario

Each of the participants was asked to complete one tutorial activity and 9 tasks in METU virtual campus. The order of the tasks is given in specific order not randomly. METU virtual campus can be divided in three areas group working area, media center and faculties and departments. First three tasks are in group working area, following two tasks are in media center and remaining four tasks in faculties and departments area. There are two goals of this specific order. The first one is that comparability of quantitative data of the participants such as task completion time and task completion length. For instance, one user completes a task such as finding social area as first task then amphitheater as second. Another participant completes a task such as finding video gallery as a first task then finding amphitheater as second. The completion time and length for finding amphitheater are too different for these two participants even though they go directly to the destination Therefore, it may

mislead the results. The second reason of not randomly given tasks is to prevent users from repeating the same routes. According to literature repeating routes in an environment leads user to memorize the routes and eventually cognition map of the environment develops in user's mind.

The participants are required to conduct the following tasks:

Task-0: Complete the welcome island tutorial of the Second Life environment.

Since most of the participants do not have prior knowledge on Second Life environment. They should have the same experience and knowledge about it. Moreover, while completing the welcome island they learn how to navigate, fly, chat and speak which is necessary in order to use second life environment properly. It consists of six steps. There are instruction boards in every step that describe to the user how s/he accomplishes that step. These steps are namely: walking by arrow buttons on the keyboard, zooming in and out on an object, chatting with other avatars around you, sitting on an object, flying and landing and finally teleporting somewhere. The participant after completing this tutorial, teleports to Middle East Technical University Second life campus. However, it was strongly advised to the participants while s/he was completing tasks not to fly. Because, flying property gives the participant a bird eye view of METU Island and this gives an idea about the locations of buildings and areas in the island. Moreover, literature says that providing bird eye view is a way finding affordance for participants. The researcher aims to make experiment with map, sign, voice and agent way finding cues in this experiment. It can be seen welcome island pictures below.



Figure 3.21 Welcome Island is the entrance of Second Life



Figure 3.22 Welcome island tutorial

Task-1: Find social area in the group work area and sit on a chair. After completing the task press F10 button on the keyboard.

Task-2: Find Amphitheatre in the group work area and sit on a chair. After completing the task press F10 button on the keyboard.

Task-3: Find Virtual Classroom-2 in the group work area and sit on a chair. After completing the task press F10 button on the keyboard.

Task-4: Find video section in the media center and watch a video. After completing the task press F10 button on the keyboard.

Task-5: Find cafe in the media center and sit on a chair. After completing the task press F10 button on the keyboard.

Task-6: Find Convention Center and sit on a chair. After completing the task press F10 button on the keyboard.

Task-7: Find Industrial Design Department floor at the Faculty of Architecture. After completing the task press F10 button on the keyboard.

Task-8: Find Faculty of Arts and Sciences amphitheater and sit on a chair. After completing the task press F10 button on the keyboard.

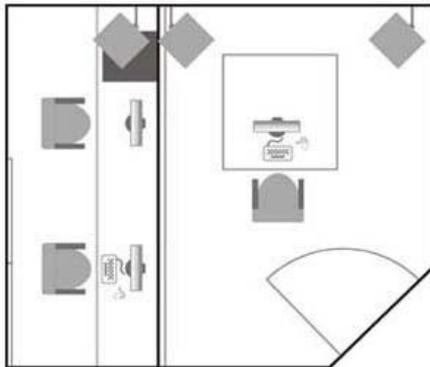
Task-9: Find Educational Sciences Department floor at the Faculty of Education. After completing the task press F10 button on the keyboard.

3.5 Study Setting

The experiments were conducted at Human Computer Interaction Laboratory at METU. This laboratory is established to evaluate web sites, computer software and so on. In the laboratory, there are two rooms: experiment and control rooms. The experiment room is sound proof, isolated from the external environment, well-illuminated and the users' movements are observed via three cameras which observe

facial activities and key board activities of the participants. There is one eye-tracker to collect data from the screen which the users look. In the control room, there are observer computer, control unit and sound mixer.

In addition the equipment existing in the laboratory, an fNIR-1000 device was brought the study setting.



(a)

(b)

Figure 3.23 (a) Blueprint of the setting. (b) View from the control room

3.6 Pilot study-1

3.6.1 Participants of Pilot-1

In the first pilot study there were three participants all of them were male aged between 26 and 30. All of the participants were students of METU, one of them has a degree from Computer Education and Instructional Technology (CEIT) Bachelor Science, one was a PhD candidate from CEIT, and the last participant has a graduate degree from Informatics Systems (IS). All of the participants reported that they use internet more than 8 hours a day. Moreover, all of the participants have knowledge about virtual worlds but none of them has membership one of the virtual worlds, also they reported that all of them play video games less than two hours in a week.

3.6.2 Experiment procedure

Before the experiment starts a brief information about eye-tracking and fNIR device is given to the participants. The participants were told that whenever s/he get uncomfortable with the experiment such as headache, nausea and etc., tell this to the researcher in order to stop the experiment. Then the participant placed in front of the eye-tracker device. There is 60 cm distance between eye-tracker and participants' eyes. This distance is measured by eye-tracker's calibration tool. After that fNIR detector was attached to participants' forehead by subject expert. Then, eye-tracker calibration process has started. Before that researcher informed the participant, a red point will appear on the screen and asked him to follow the red point while it moves on the screen. A program named sun suite protocol executor starts fNIR data recording than shows a black screen with plus sign in the middle during 20-30 seconds to participant in order to get a base line of the participants' preferential lobe for fNIR data set. Than Second Life application started user's avatar enters welcome island where every avatar should complete prior to teleport main lands. In fact, welcome island of the second life is a kind of basic tutorial which every user should learn how to use the second life environment. It consists of six steps. There are instruction boards in every step that describe to the user how s/he accomplishes that step. These steps are namely: walking by arrow buttons on the keyboard, zooming in and out on an object, chatting with other avatars around you, sitting on an object, flying and landing and finally teleporting somewhere. The participant after completing this tutorial, teleports to Middle East Technical University Second life campus. Since the campus was not completed, users were required to complete tasks that related group working area. Group working area consists of two working towers, two virtual classrooms, an amphitheater, group meeting areas, social area and dancing area. Before giving tasks to the participant the researcher wants them to tell what s/he is thinking why they are doing certain actions. Then, the first task was given to the participant by the researcher and told him/her if s/he thought complete the task after that a new one was given. There four tasks: getting south working tower's 3rd floor and sitting on a chair; finding one of the virtual classrooms and sitting on a chair; finding the amphitheater and sitting on a cushion and finding social

are and sitting on a chair. fNIR subject expert put a marker after the participant completing the given task or doing specific actions. These markers were used to synchronize eye-tracker screen recording and fNIR data. Pilot-1 experiment setup can be seen in the following picture.

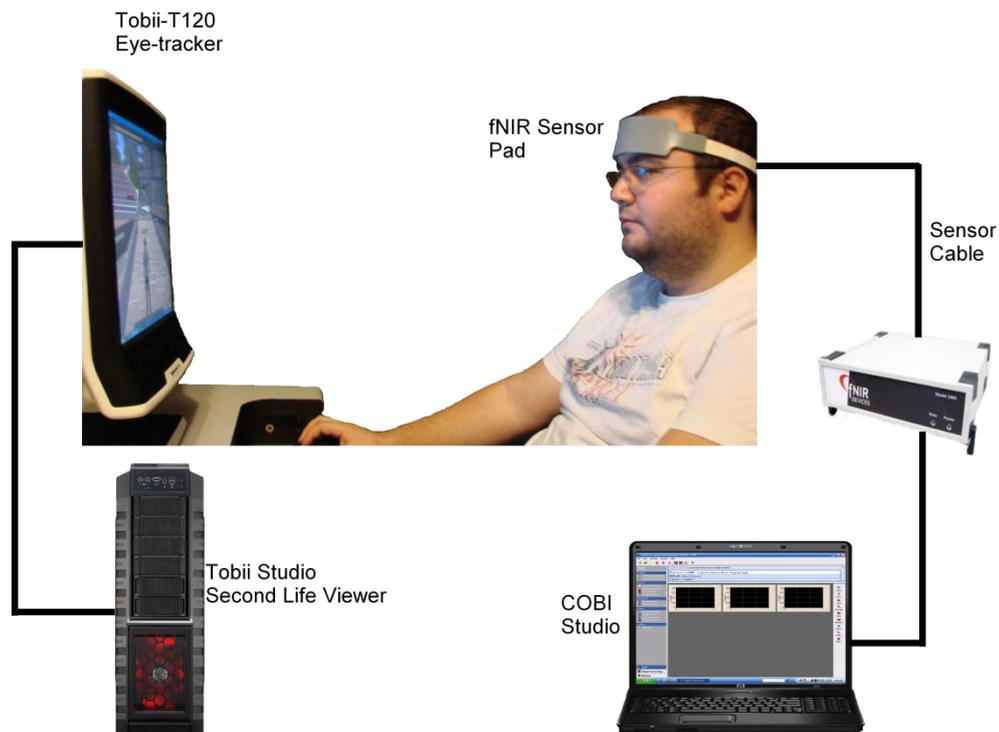


Figure 3.24 Pilot-1 experiment setup

3.6.3 Problems found in pilot-1 study and solutions

After gathering both fNIR and screen recording of eye-tracking data it was detected that fNIR markers and screen recording data could not be synchronized well. There were inconsistencies in data. Therefore, fNIR subject expert write a program that sends the information when pressed pre-defined button on the keyboard. The researcher determined space button on the keyboard to get new task and this information was sent to fNIR as a marker by the program.

Moreover, fNIR subject expert stated that think aloud process could deteriorate fNIR data. Therefore, it has been decided that participants not to talk as much as they can during experiment.

In addition, one of the subjects completes all of the tasks by flying. Flying gives the ability of seeing entire environment view therefore the participant easily and quickly was able to complete the tasks. Moreover, flying and seeing bird eye view of the environment seen as a way finding affordance in the literature. Therefore, it has been decided that participants asked to complete the tasks on foot.

3.7. Pilot study-2

In order to test new corrections of experiment setup and find new problems and solutions second pilot study was conducted.

3.7.1 Participants of Pilot-2

There were four participants in pilot-2 all of them were male. However, Tobii could not detect one of the participants' pupils because of the participant's glasses. Therefore, the experiment was aborted since any reliable eye-tracking data obtained. All of the participants were students of METU, one of was a PhD candidate from Computer Education and Instructional Technology (CEIT), one was a PhD candidate from department of Biology, and the last participant was a master of science candidate from Informatics Systems (IS). All of the participants reported that they use internet more than 8 hours a day. Moreover, all of the participants have knowledge about virtual worlds but none of them has membership one of the virtual worlds, also two of the participant reported that plays video games more than eight hours in a week, and the other plays video games between 2 and 4 hours in a week.

3.7.2 Experiment procedure

In the second pilot study in addition to the ones in the first pilot study the followings were performed. The tasks the participants should complete were given by the tobii software not by the researcher. Moreover, in the second pilot study participants filled

a participants' information questionnaire which was having questions about participants' demographic data. It can be reached from Appendix-C. Moreover, the researcher filled an observation form for each participant. After the participant completed experiment, a system usability scale (SUS) questionnaire was filled by the participant. Then, a short interview was made with the participants.

In spite of all these developments it was noticed by fNIR subject expert that fNIR detector's signals were noisy because of the eye-tracker's infrared lights. Therefore, it was needed an insulator between fNIR and eye-tracking devices. Subject expert consultant to a material engineer for such an insulator and aluminum folio was proposed. fNIR detector attached to the participants forehead fNIR detectors' outer surface covered with aluminum folio. Pilot-2 experiment setup can be seen in the following picture.

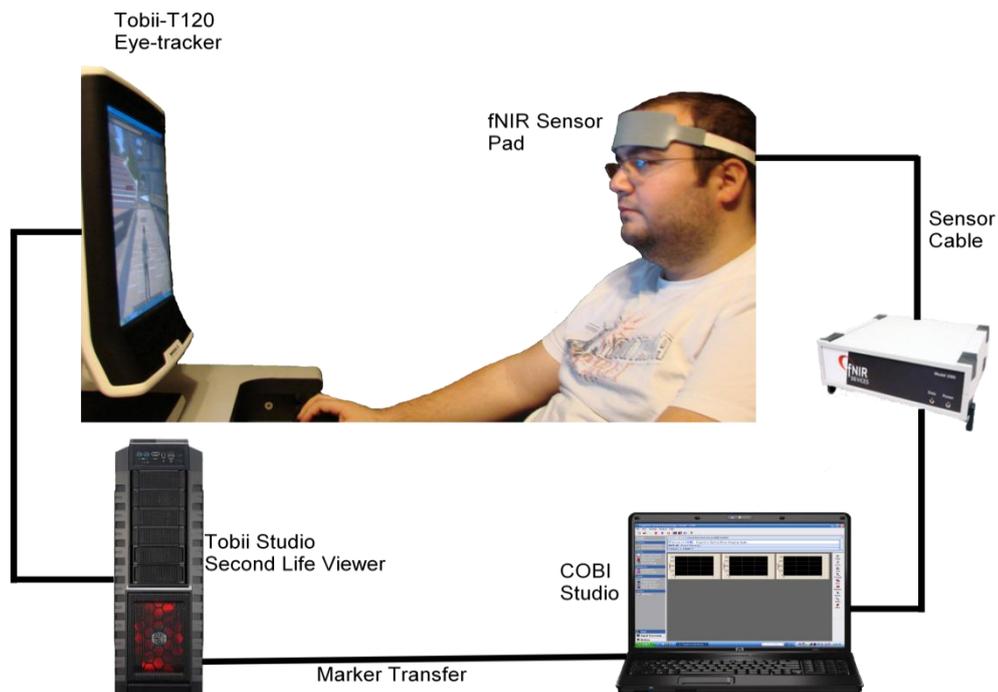


Figure 3.25 Pilot-2 experiment setup

3.7.3 Problems found in pilot-2 study and solutions

An insulator needed between fNIR detector and eye-tracking device. Moreover, there was a second problem about interfering fNIR signals which is ambient light. Ambient light leakage occurs between sensor pad and participant's forehead. This leakage needed to be stopped for the benefit of fNIR signals. The solution of the problem was to cover the sensor pad and aluminum folio with a bandana and also covering top of the sensor pad with a second bandana.

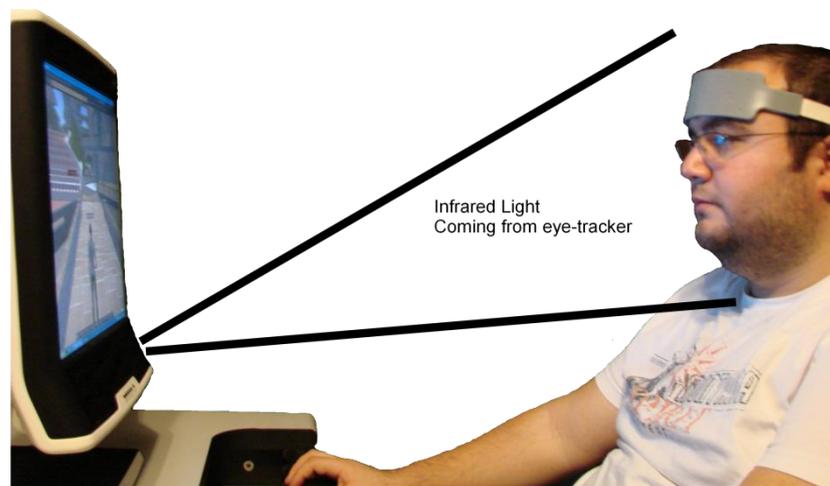


Figure 3.26 Infra red lights coming from eye-tracker

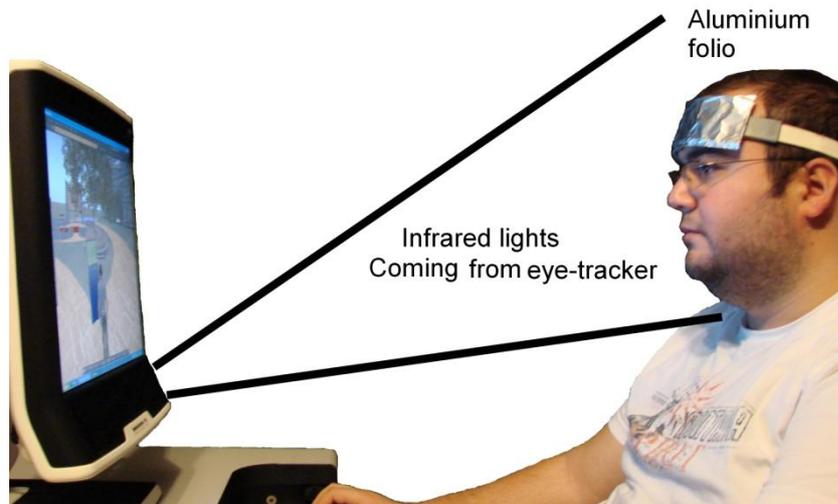


Figure 3.27 Solution of interfering infrared light

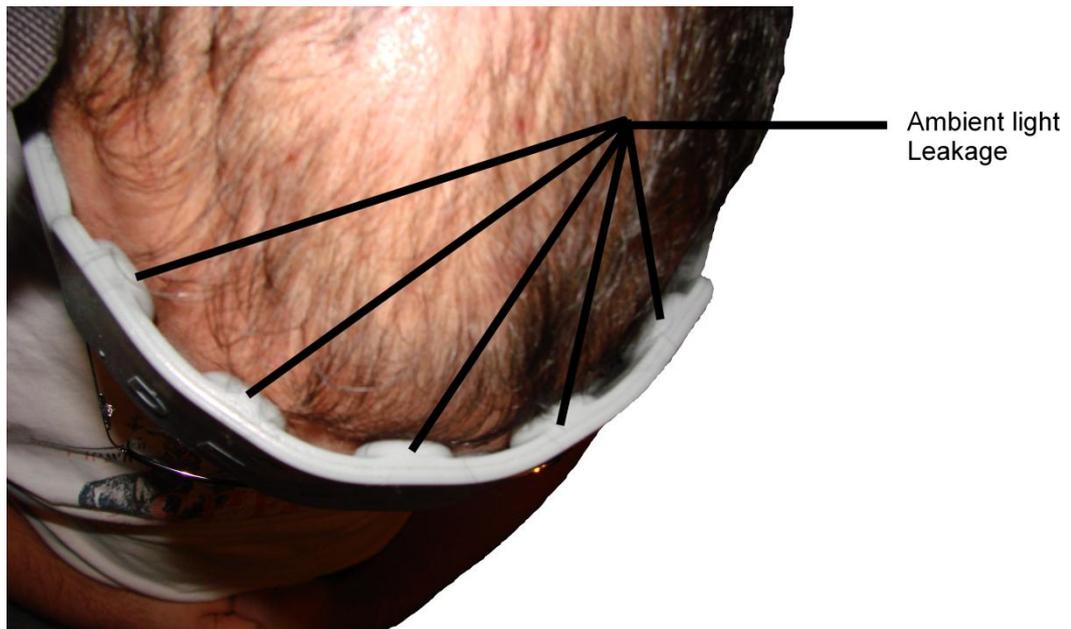


Figure 3.28 Ambient light leakage



Figure 3.29 Covering sensor pad with bandana

3.8 The main experiment

Before the experiment starts a brief information about eye-tracking and fNIR device is given to the participants. The participants were told that whenever s/he get uncomfortable with the experiment such as headache, nausea and etc., tell this to the researcher in order to stop the experiment. A consent form and participant information form were filed then participant placed in front of the eye-tracker device. There is 60 cm distance between eye-tracker and participants' eyes. This distance is measured by eye-tracker's calibration tool. Participant asked to wipe off his/her forehead with wet wipe in order to remove unwanted material such as sweat, make up or cream etc. After that fNIR detector was attached to participants' forehead by subject expert. Then fNIR detector was covered by aluminum in order to protect fNIR data from eye-tracking device's infrared light. Then, the program was run that send the marker from participants computer to computer that fNIR connected. During this installation brief information about the METU virtual campus in the second life environment was given to the participant. Moreover, it was stated that to the participant try to complete the given tasks without using their prior knowledge on real METU campus since virtual METU campus does not look like the real one.

Then, subject expert asked from participant to close his eyes and try not to think anything about 20 to 30 seconds. This procedure was done for getting base line for fNIR data. After that fNIR device starts recording. After that, eye-tracker calibration process has started. Before that researcher informed the participant, a red point will appear on the screen and asked him to follow the red point while it moves on the screen. If there were any calibration problems they would be repeated before the experiment. The participant needed to complete welcome island tutorial to learn necessary skills s/he would use during the experiment. After completing the tutorial, the participant is teleported to the METU virtual campus. Before starting the tasks a message appears on the screen that warns the participant during the tasks s/he should not fly or speak in order to fNIR data accuracy. The main experiment consists of 9 tasks. During the experiment the researcher filled the observation form. After completing all of the tasks or the participants wants to quit fNIR detector and folio detached from the participant. SUS questionnaire was filled by the participant. After that a short interview made about the experiment.

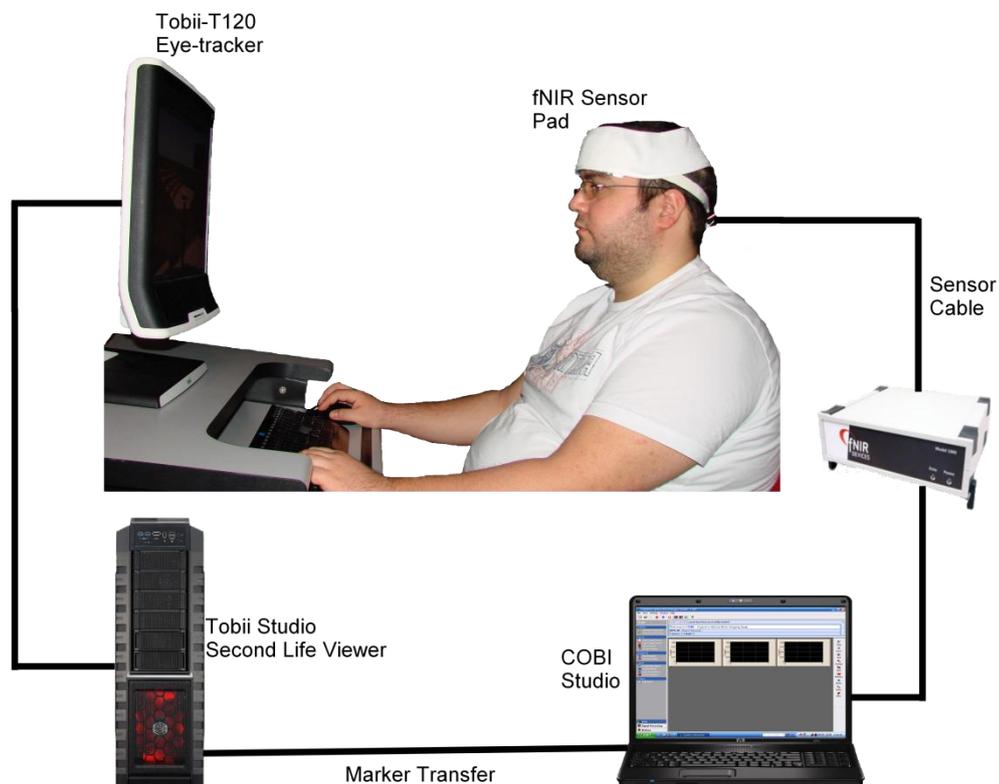


Figure 3.30 Main experiment setup

The procedures of pilot and main study are summarized in the figure below.

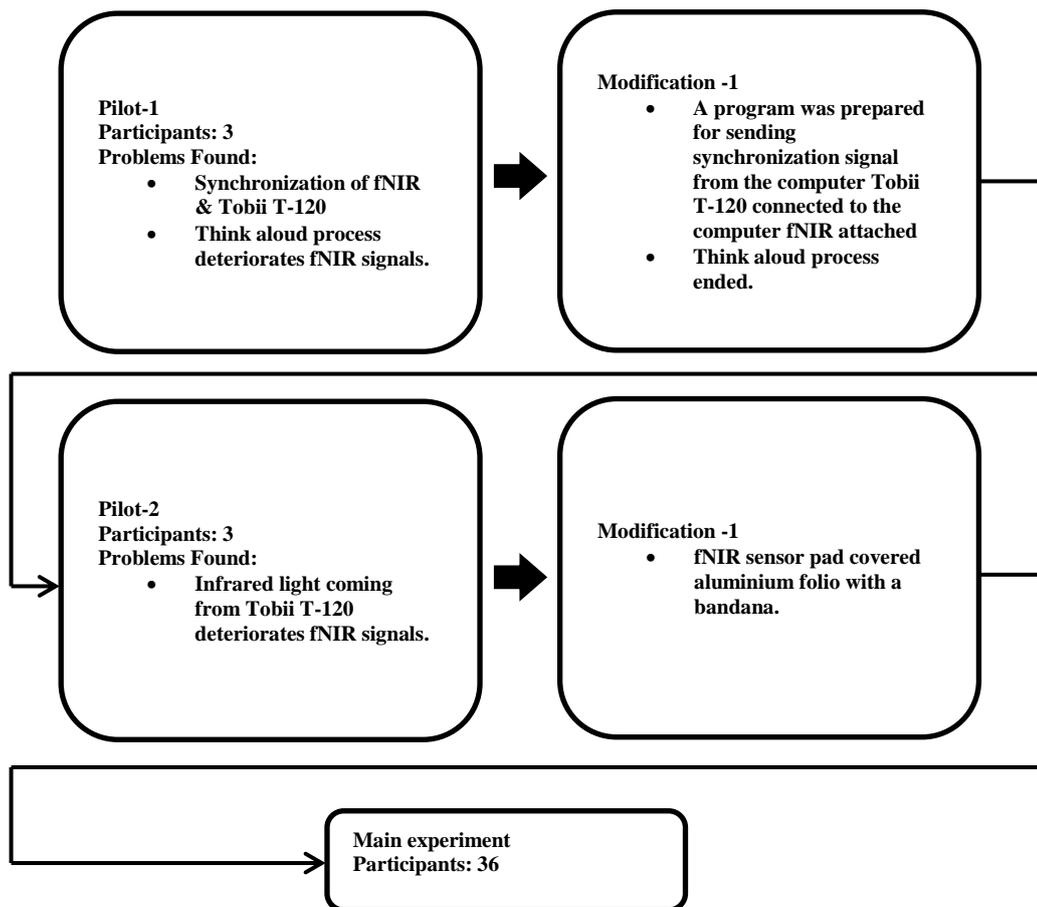


Figure 3.31: Setting Schema of the whole study

3.9 Validity reliability and Trustworthiness

This is an experimental quantitative study. Although the quantitative data takes important role in the analysis of the study, in order to get deeper understanding about treatments, semi-structures follow-up interviews were conducted with each participant.

The purpose of this study was to investigate way finding affordances in a 3D virtual environment under different conditions namely map, sign, voice, and agent. Each setting was designed according to the nature of the corresponding setting.

Combining different methodological approaches increases the validity and reliability of the study (Hassanien, 2006). The follow-up interviews also were made with each participant. This also increases reliability of the results.

The questionnaire questions were adopted SUS. The cross-translational procedure was applied for translating the System Usability Scale to Turkish. 7 researchers took role in this process.

TOBI interface is controlled by the experts of Human Computer Interaction Labs at METU Computer Center.

fNIR expert collected data himself. His experience and opinions during each pilot study revealed and solved different and critical problems of setting up the experiment, so that eye tracking and fNIR devices worked together properly.

3.10 Data collection

The experiment was conducted with the permission of Ethical Committee Appendix-A. After pilot studies, cross translation of System Usability Scale (SUS), construction of demographic questionnaire and follow-up interview questions were completed. The following figure represents the whole data collection procedure.

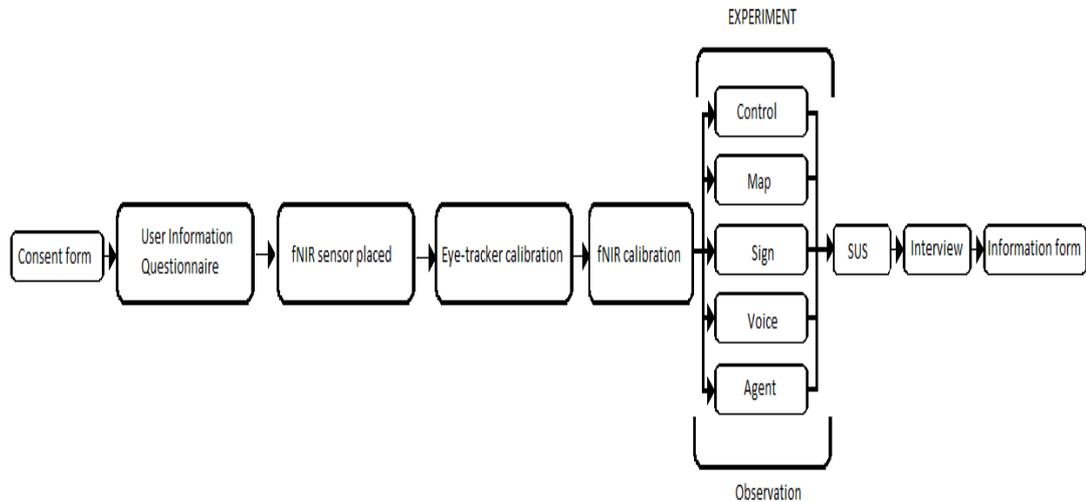


Figure 3.32 Data collection procedure

In order to find participants for the study an e-mail asking fill in the demographic questionnaire attached was sent to a list whose members are subscribed to human computer interaction laboratory at METU for usability studies voluntarily. 58 questionnaires were collected 29 of them male and 29 of them female. Education level of all participants was 42 B.S., 11 M.Sc. and 5 PhD students. 19 of the participants were unaware of virtual worlds, 30 of them were aware of virtual worlds but had no membership and 9 of them were member at least one virtual world.

30 of them were available for the experiment. The participants were randomly put into four treatment groups and a control group. At first each treatment and the control group have 6 participants of them 3 male and 3 female. However, after completing some experiments it was observed that some participants' pupils tracking rate below %50, therefore those experiments were conducted again with different participants.

After completing the experiment participants filled the SUS questionnaire then semi structured follow up interview made . Finally, user information was given the participants.

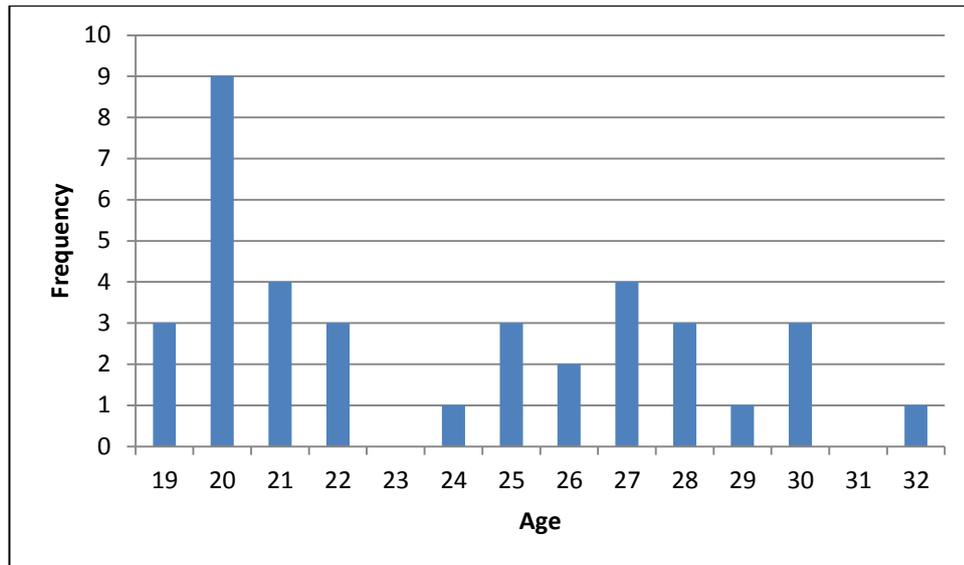


Figure 3.33 Age distribution of participants

3.11 Participants

Table 3.1 Participants in the main experiment

	Female	Male
Control group	3	6
Map group	6	3
Signboard group	4	3
Voice group	3	3
Agent group	3	3

There were 37 participants in the main experiment 19 of them male and 18 of them female. Education level of participants were 24 B.S, 8 M,Sc., 5 PhD. 12 participants were unaware of virtual worlds, 22 of them have some knowledge about virtual worlds but have no membership any of virtual worlds.

There are four treatment groups and one control group in this study. Number of participants in the control group was 9, 6 male and 3 female. During the experiment one of the male participant felt nausea and the researcher abort the experiment and his fNIR and eye-tracker data could not be used. There were 9 participants in map treatment, 3 male and 6 female. One of the female participant data could not be used because internet connection was lost and tobii studio aborted. Other two female participant's pupils tracking rate was below %50 therefore these participant's eye-tracking data could not be used but fNIR and other data were used. There were 7 participants in sign treatment 3 male, 4 female. One of the female participants eye-tracking data could not be used because of eye-tracker rate was below %50. There were 6 participants in both voice and agent treatment groups.

3.12 Data analysis

In order to increase reliability and validity of the study both qualitative and quantitative methods were conducted.

3.12.1 Quantitative Analysis

Demographic data from the user information questionnaire (age, gender, level of education, department, virtual world membership status, video game playing frequency) filled by the participants, and were evaluated with SPSS 20 for Windows (SPSS Inc., Chicago,IL, USA).

Other data (task completion time, etc.) were calculated from the participants' experiment screen recording with using Microsoft Excel 2010 and SPSS. After the experiment, satisfaction scores (sus) were evaluated according to satisfaction questionnaires of the participants with Excel 2010 AND SPSS.

One-Way Analysis Of Variance (ANOVA) was conducted with five treatments (control, map, signboard, voice, and agent) as independent variables, for the dependent variables (total time, length, eye-tracking results (standard signs and

treatment signs), fNIR results). Results showed that whether there was a mean difference between 5 independent groups on a single dependent variable ($p < 0.05$).

Then, one-way repeated measure ANOVA was conducted with 5 treatments (control, map, signboard, voice, and agent) as independent variables for the 9 task completion time within subject. Results showed whether there is a significant difference between each task completion time across treatment groups. ($p < 0.05$).

After, One-Way Multiple Analysis of Variance (MANOVA), was conducted with five treatments (control, map, signboard, voice, and agent) as independent variables for the dependent variables (time, length, accuracy and satisfaction). Results showed that mean difference among treatment groups on the combined dependent variables (total time, total length, accuracy, satisfaction). ($p < 0.05$).

Least Significant Difference (LSD) and test was applied as a post-hoc test if a factor had a significant effect. LSD Results explored all possible pair-wise comparisons of means comprising a factor using the equivalent of multiple t-tests. Bonferroni test had more power when the number of comparisons was small.

3.12.2 Qualitative Analysis

Qualitative data gathered from follow up semi structured interview with each participant. Each participant's answers were written down on the interview sheet (Appendix-F) by the researcher exactly what participant said. Then the answers were typed into word processor than segmented, coded and enumerated to find frequency of related category. Qualitative data were converted into numbers in order to increase reliability and objectivity (Yıldırım& Şimşek, 2000).

3.12.3 Path Analysis

All participants recorded videos were watched and the route they took to complete for each task was drawn on a standard bird eye view of the METU virtual campus by hand then these routes were drawn with a program name is Inkscape to measure the

length of each route. After that these routes were superposed by treatment groups and by tasks.

3.12.4 Eye-Tracking Analysis

Each experiment was recorded by Tobii studio 2.2.4 in a data directory. After all experiments completed, each participant's performance was examined frame by frame by the researcher. Since the experiment was conducted in a 3D environment the screen captured by the Tobii studio changes very rapidly. Tobii software analysis tools are designed mostly for 2D environments such as web sites. Therefore, Tobii studio's analyze tools could not be used for this study. The researcher calculated the total fixation time on area of interest by counting the fixations (Karacan, 2007).

3.12.5 fNIR Analysis

During the experiment the participants were able to begin new tasks by pressing space bar. When the participant presses the space bar on the keyboard a program sends a marker to the laptop computer running COBI software. With the help of this program fNIR expert was able to see when the participant begins the task. Each participant's task completion times were detected by watching the participant's screen capture video in terms of seconds. fNIR signal blocks were detected by adding task completion time on the time when the user pressed space bar for each task.

First, linear phase, finite impulse (FIR) low pass filter with cut-off frequency of 0.14Hz was applied to the 16 voxel raw fNIR data to eliminate high frequency noise due to physiologically irrelevant data (such as respiration and heart pulsation effects) and equipment noise. Then, Sliding Windows Motion Artifact filter (Ayaz et al., 2010) was employed to minimize the effect of motion artifact on the measurements. Finally, modified Beer Lambert Law (Izzetoglu et al., 2005) was applied to the filtered fNIR data to calculate the changes in oxy-hemoglobin and deoxy-hemoglobin concentration.

3.12.6 Missing data

There was no missing data on user information questionnaire, SUS and follow up interview. However, eye-tracking and fNIR device could not provide all data. Due to feeling nausea few participants left experiment early. Moreover, because of insufficient illumination of the lab environment eye-tracker could not provide all data. Eye-tracker provide time, length and gaze duration. Those missing data replaced with group's mean in order not to lose any participants. Moreover, theoretically fNIR device has to provide 16 set of data but this could not be achieved in this study. Because fNIR sensor pad was standard sized and every participant's physiological aspects were different therefore 16 data set could not be gathered. After all experiments finished it was observed that voxel-2, 4, 6, 12, 14 and 16 collect data almost from all participants. The missing data in those sets were replaced with mean of the group.

3.13 LIMITATIONS

During experiment the following limitations were observed.

3.13.1 Eye tracker limitations

Tobii Studio 2.2.4 was design to analyze 2D environments such as web pages. However, this experiment was conducted in a 3D environment. The software has the ability of defining area of interest but this feature works properly in 2D settings. For instance, an area of interest was set on the screen covering an object in 3D environment; coverage of this area of interest would change when the avatar changes its position. When it happens, even if selected area covers different objects; the software could not aware of this change and it continuous the analyze process. Eventually the result is not correct. Therefore, analyze process needed to be done by frame by frame. The new version of Tobii Studio 3.0 provides 3D analyze tools, but in time of this study was conducted Tobii Studio 3.0 was not available in METU HCI laboratory. Therefore, all analyze process was done with Tobii Studio 2.2.4.

Moreover, Tobii T-120 eye tracker device needs average ambient light in order to track the participant's eye. But, average ambient light deteriorates the fNIR signals.

3.13.2 fNIR limitations

fNIR device has the ability of detecting signals from prefrontal cortex only. Other parts of the brain could not be investigated by fNIR device. Due to this feature of the fNIR, data collected from the participants' prefrontal cortex only.

The sensor pad of fNIR device produced with standardized dimensions. There were no specific sensor pads for male or female participants. Therefore, both female and male participants had to wear same sensor pad. Odd numbered sensors were located upper side of the pad; even numbered sensors were located in bottom side of the pad. The pad was little much bigger for female participants' forehead. Therefore, the sensors located upper side of the pad could not be placed right locations. In fact they contacted most of the female participants' hair. However, the sensors located upper side of the pad placed properly on most of the male participants' forehead. The reason of the difference was generally female forehead smaller than male ones.

Even though the pad was located properly, the ambient light leakage happened resulting in deterioration of fNIR signals. Moreover, the participant's talking during experiment and movements also could damage the fNIR signals. After second pilot study it was discovered that infrared light coming from the eye-tracker device deteriorate fNIR signals. The subject expert covered the sensor pad with aluminum folio as an insulator.

3.13.3 Hardware limitation

Prior to the pilot studies it was discovered that there was a compatibility problem in the experiment setup. The experiment components were listed below:

-PC

CPU: AMD Phenom X4 B95

RAM: 3 GB DDR2

VGA Card: MSI Geforce N210 MD1G/D3

OS: Win7 64 Bit

-SL Viewer: SL viewer 3.2.1.4

-Eye-tracker software: Tobii studio 2.3.2

In this setup when screen recording started avatar could not move toward right or left. But the avatar moved easily forward or backward. After, several hardware, operating system and software the problem solved by changing operating system Win7 64 bit to Windows XP 32 bit and downgrading Tobii Studio 2.3.2 to 2.2.4. However, when the hardware of the setup upgraded to newer and better versions but remaining OS and software the same versions; uncovered new compatibility problems. Therefore, previous working setup created again as main experiment setting as listed below:

-PC

CPU: AMD Phenom X4 B95

RAM: 3 GB DDR2

VGA Card: MSI Geforce N210 MD1G/D3

OS: Windows XP 32 Bit

-SL Viewer: SL viewer 3.2.1.4

-Eye-tracker software: Tobii studio 2.2.4

However; the experiment setup was not very capable of screen recording and providing Second Life environment to the participants at the same time at high speed. The participants who described themselves as gamer reported the situation as frame per second (FPS) was low. However, non-gamer participants did not report such in incident.

3.13.4 Treatment limitations:

Seven agents needed to be designed and developed in order to use in the experiment. However, it was unlikely to develop those agents due to the time limit and lacking of necessary programming knowledge. Therefore, those agents were simulated by real persons. The instructions they needed to provide to the participants provided them as soft format. It was asked them to reply those provided instructions to the

participants' needed. The limitation in this process was the delay between the participants asking to the agent and replying instructions to the participants. If the agents had been created, the delay would have been much less.

CHAPTER 4

RESULTS

Throughout this chapter demographics, quantitative data analysis, qualitative data analysis and usability issues will be covered in detailed. One-way and repeated ANOVA and MANOVA analysis were conducted to reach detailed answers about the research questions. Moreover, total and individual scores of the groups were represented by graphs.

4.1 Demographics

The participants' demographics collected via user information questionnaire the users' information is presented in the following sections.

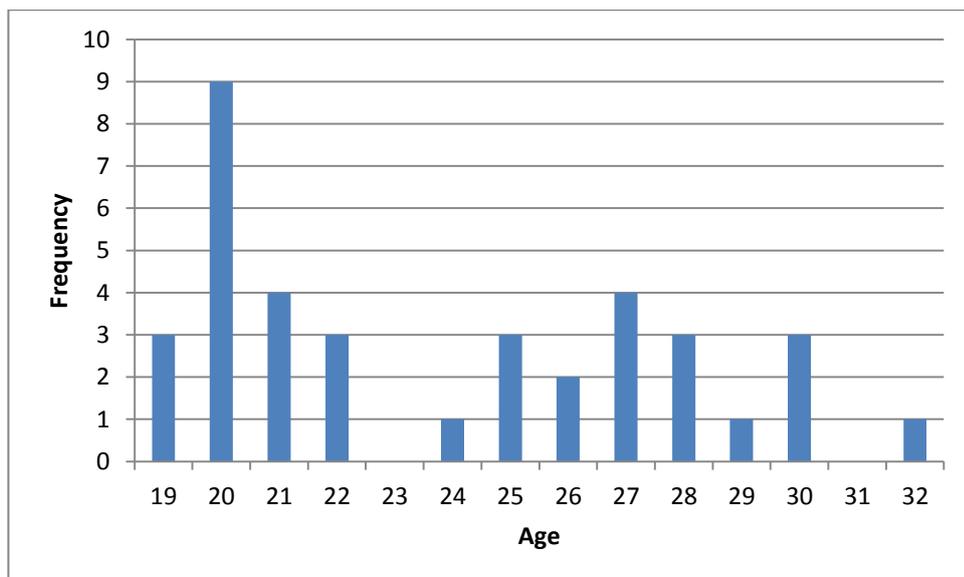


Figure 4.1 Age distribution of participants

There were 37 participants' ages between 19 and 32 in the study. 24 of them were students from under graduate departments, 8 of them graduate schools (Figure 4.1) and 5 of them Ph.D. at METU 19 male and 18 female participants were in this study.(Figure 4.2) 12 of the participants were unaware of virtual worlds before this experiment. 22 of them were aware of virtual worlds but they do not have any membership any of the virtual worlds (Figure 4.3). Only 3 of the participants were members at least one of the virtual worlds. In fact, two of these memberships were in Second Life and the other was in Sims (Figure 4.4). 6 subjects reported that they connect internet less than two hours in a day; 15 of them use internet between 2 and 4 hours in a day; 6 of the subjects use internet between 4-6 hours and 1 participant connects to internet between 6 and 8 hours and remaining 9 participants reported that they use internet more than 8 hours in a day (Figure 4.5). Moreover, alternative demographic information about the users collected via user information questionnaire was users' game playing habits. 7 of the participants reported that they do not play video games. 30 of them play video games. 22 of them play less than two hours in a week. 3 of them play between 2 and 4 hours and 1 user plays between 4 and 6 hours, 4 of them play video games more than 8 hours in a week (Figure 4.6).

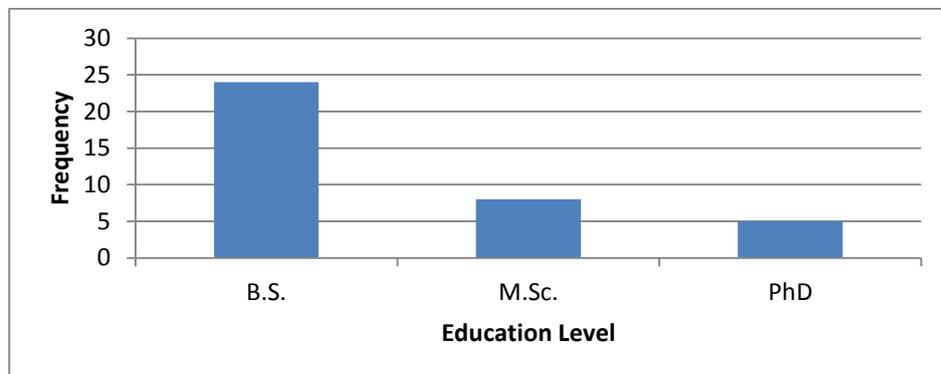


Figure 4.2 Education level distributions of participants



Figure 4.3 Virtual world awareness distributions of participants

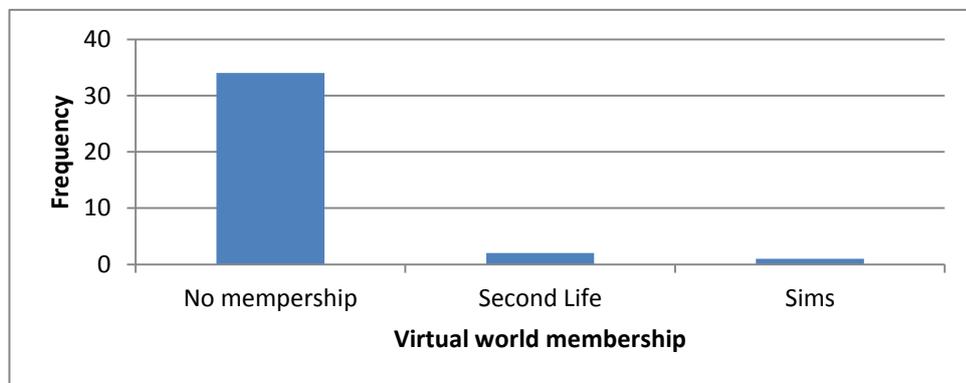


Figure 4.4 Virtual world membership distributions of participants

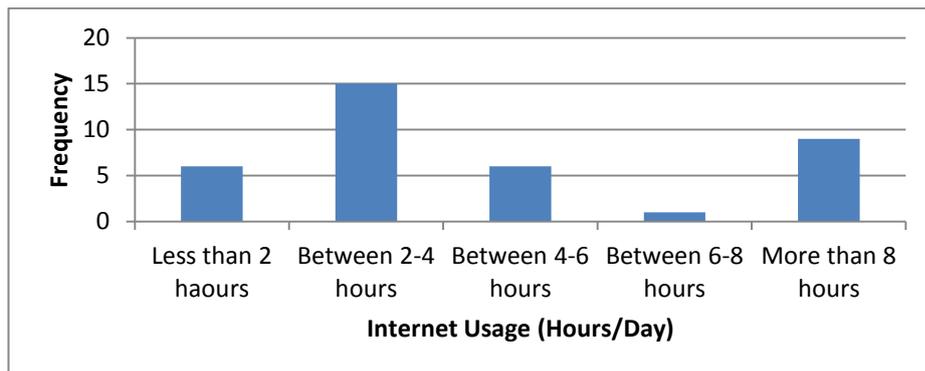


Figure 4.5 Internet usage distributions of participants (Hours/Day)

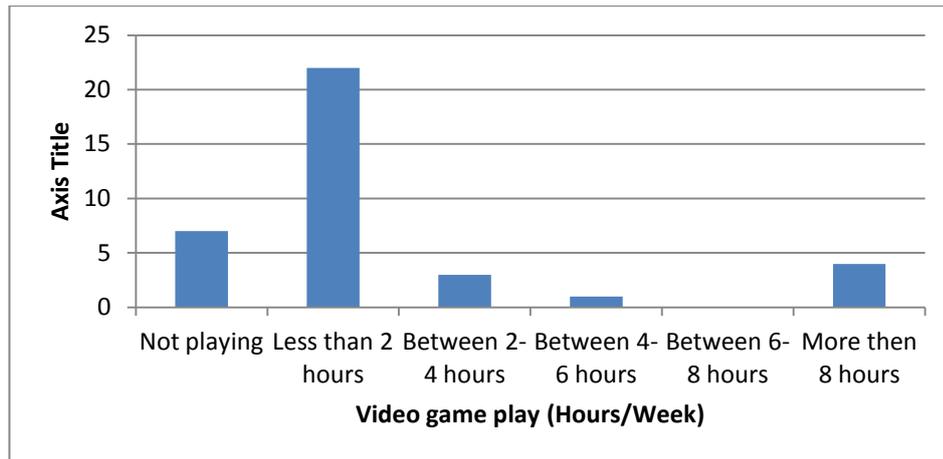


Figure 4.6 Video game play distribution of participants (Hours/Day)

4.2 Usability Issues

This part of the study aims to identify the impact of navigational affordance on usability in virtual campus environment. The eye tracking device and performance analysis which is considered as classical usability study are used for this purpose. The eye tracking device measured how many times and where the participants looked at in the environment. In addition, performance analysis consisted of total time for and length traveled over during completion of a task and also success in the task.

In this study, user based usability methods were used. Nine tasks which included basic properties of the environment and in turn reflected the aim of the study were determined. The eye tracking device was used to record the acts of the users. By means of this device, the route that any user followed and the time that a user required to complete the task were recorded. The areas that the users focused were also been noted.

The tasks given to users which they had to complete by using virtual campus environment are as below:

Task-1: Find social area in the group work area and sit on a chair. After completing the task press F10 button on the keyboard.

Task-2: Find Amphitheatre in the group work area and sit on a chair. After completing the task press F10 button on the keyboard.

Task-3: Find Virtual Classroom-2 in the group work area and sit on a chair. After completing the task press F10 button on the keyboard.

Task-4: Find video section in the media center and watch a video. After completing the task press F10 button on the keyboard.

Task-5: Find cafe in the media center and sit on a chair. After completing the task press F10 button on the keyboard.

Task-6: Find Convention Center and sit on a chair. After completing the task press F10 button on the keyboard.

Task-7: Find Industrial Design Department floor at the Faculty of Architecture. After completing the task press F10 button on the keyboard.

Task-8: Find Faculty of Arts and Sciences amphitheater and sit on a chair. After completing the task press F10 button on the keyboard.

Task-9: Find Educational Sciences Department floor at the Faculty of Education. After completing the task press F10 button on the keyboard.

4.2.1 Performance Analysis

For all tasks and users with respect to their groups; the total time and length traveled in order to complete task and success rate are calculated as below. Total performance data of all participants for each task are available in the above table. In addition, the problematic areas in terms of usability can be seen clearly from the above table. The total time and length and also success rate for different way finding affordance

groups are calculated. Each task is interpreted within itself. The best and the worst performances are signed with respectively, yellow and red colors. For instance, for Task 1, the worst group in terms of time is map group whereas, the best is agent group. When overall data is observed, it is deduced that the map group participants followed the longest way within the longest time. The red color concentration of map group represents usability problematic issues. On the other hand, signboard group was the best performing group in terms of time and voice group in terms of length. Although nearly all agent group participants completed the tasks successfully, signboard and voice group participants were also successful in completing tasks. It is concluded that map affordances are not effective with respect to usability while signboards were more effective than other affordance groups in this study.

Table 4.1 Total Length & Time vs. Treatments

	Map group			Signboard group			Voice group			Agent group			Control group		
	Total Time	Total Length	SR	Total Time	Total Length	SR	Total Time	Total Length	SR	Total Time	Total Length	SR	Total Time	Total Length	SR
Task 1	2031,178	360,57	6/9	1036,89	194,86	7/7	1851,158	367,31	6/6	804,232	93,39	6/6	1203,364	330,29	2/8
Task 2	1360,447	260,24	7/9	451,519	110,7	5/7	418,155	95,63	6/6	585,834	116,65	1/6	1643,194	437,68	3/8
Task 3	1688,596	342,56	8/9	374,516	82,57	6/7	278,129	63,41	6/6	489,36	65,48	6/6	1469,983	411,14	3/8
Task 4	3088,238	599,56	8/9	1141,543	260,69	7/7	1240,293	302,44	6/6	1638,79	334,32	6/6	1613,302	438,37	8/8
Task 5	394,956	103,28	9/9	325,353	79,01	7/7	284,559	64,37	5/6	261,712	65,08	6/6	357,175	100,44	8/8
Task 6	906,915	211,35	9/9	470,065	144,89	7/7	497,016	143,01	6/6	639,369	145,83	6/6	608,281	188,77	8/8
Task 7	1525,067	285,34	9/9	760,657	161,16	7/7	1050,924	270,89	5/6	1004,044	204,57	6/6	1005,815	313,01	8/8
Task 8	2042,451	430,522	7/7	1266,886	360,59	7/7	821,002	251,02	6/6	854,307	258,9	6/6	1152,939	321,93	7/8
Task 9	2123,443	391,655	7/7	737,709	245,51	7/7	853,275	206,82	6/6	838,332	203,94	6/6	1079,618	311,44	8/8

4.2.2 Eye tracking data analysis

During the experiments, the eye movements of the participants were recorded with Tobii T120 Eye Tracking Device. Analysis was conducted via Tobii Studio 2.2.4. Detailed information is available in Chapter 3.11.4 The eye-tracking device gives information about where the users look at, for how long time, and with how many gaze. The device also gives concentration data of the users. However, as it is explained in the limitations of the study, because the environment is in 3D and dynamic; where the participants concentrated cannot be detected numerically. By this means, the attractive navigation affordance is determined.

Table 4.2 Gaze duration vs. Treatments

	Map	Signboard	Voice	Agent
Task 1	506,277	194,106	276,114	197,574
Task 2	123,216	69,258	30,498	82,008
Task 3	191,607	69,717	23,664	42,279
Task 4	518,568	113,22	76,551	249,033
Task 5	29,886	10,353	NA	0,663
Task 6	191,301	46,155	28,356	108,528
Task 7	322,218	100,011	72,522	148,563
Task 8	175,797	62,22	41,871	86,649
Task 9	126,327	60,027	55,233	26,469

Each task is interpreted again within itself. The total time that the participants spent for looking at each navigation affordance is calculated for each task. Pink areas represent that for that task, the group includes the least attractive affordance; thus the participants do not prefer to look at that affordance. As it can be understood from the high density of pink areas in the voice group cells, the voice navigation was the least attractive for the participants. Furthermore, it is concluded that map affordance is the most attractive one for the users since the blue cells show the group which incurs the highest number of gaze. However, it is considered as that the maps require more effort to interpret due to design issues, and as a result the users look at maps for a longer time than other affordances.

4.2.3 Participant Questionnaire Analysis

System Usability Scale (SUS) is used in order to make analysis of the participant satisfaction level. The overall SUS Scores for each affordance group are given in the table below. The highest score which is close to 100 belongs to signboard group. Thus, signboard group supports the usability of the environment mostly according to the participants' views.

Table 4.3 US vs. Treatments

Treatment	SUS Score
Control	55,31
Map	58,33
Signboard	74,64
Voice	71,25
Agent	65,42

4.3 Quantitative Data Analysis

In order to reach conclusive results descriptive and inferential statistical methods were utilized. In general, for all dependent variables defined in Chapter 3.2, one-way ANOVA, repeated measures ANOVA and MANOVA were conducted.

4.3.1 User Satisfaction

Users' satisfactions on the treatment were collected by SUS. Its computation was explained in detail in Chapter 3.3. Descriptive statistics is shown Table 4.1 and user satisfaction vs. treatment graph is shown in Figure 4.7.

Table 4.4 Descriptive statistics of US dependent variable

	N	Mean	Std.Dev.	Skewness	Kurtosis
US	36	64.17	16.26	-0.65	0.20

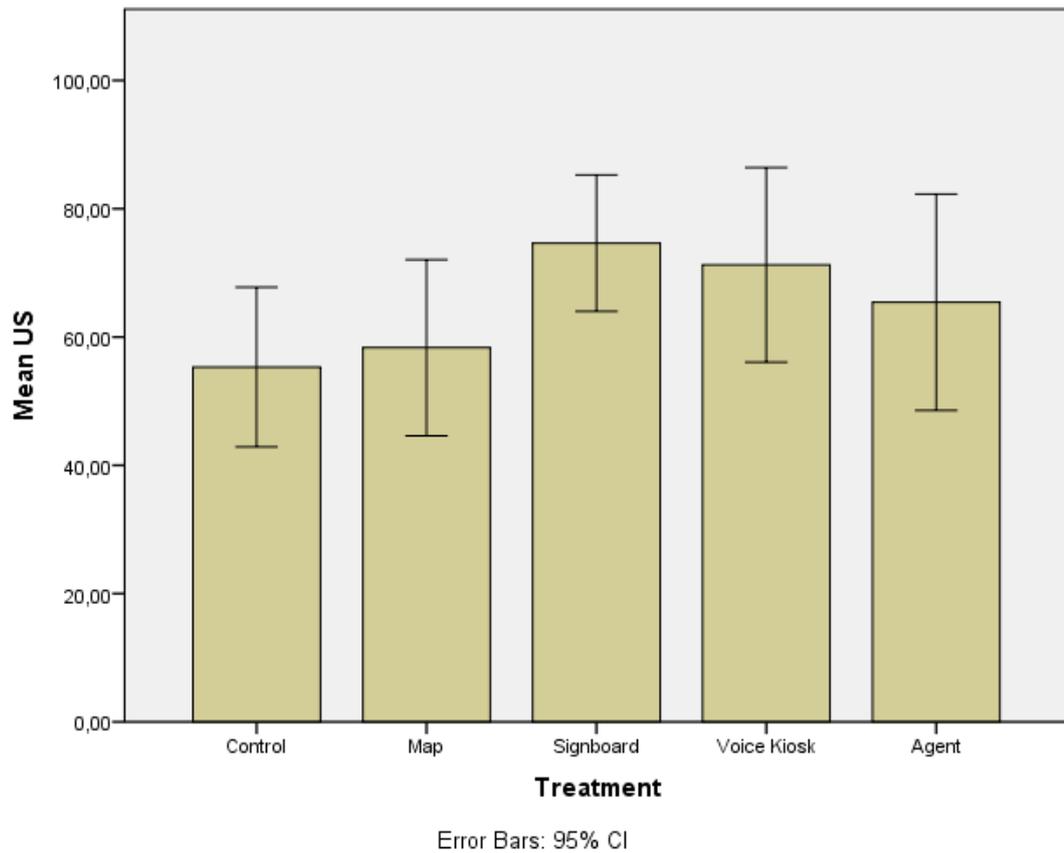


Figure 4.7 User Satisfaction for Treatment groups

Figure 4.7 shows that the participants used sign board were more satisfied with the environment than the other treatment groups with 74.64. On the other hand, control group's participants were the least satisfied with the environment. With the score 55.31.

To investigate is there significantly mean difference between treatment groups in terms of US one-way ANOVA was conducted.

Table 4.5 Levene's test of equality of variances for US dependent variable

	<i>F</i>	df1	df2	<i>p</i>
US	0.6175	4	31	0.654

Table 4.6 ANOVA result with respect to US dependent variable

Source	df	<i>F</i>	<i>p</i>	Eta-Squared	Observed Power
Treatment	4	2.154	0.98	0.218	0.568

According to Table 4.5 Levene’s test of equality of error variances did not yield any significance difference therefore one-way ANOVA test assumption has met. With respect to Table 4.6 ANOVA did not yield significant difference between treatment groups in terms of user satisfaction score $F(4,31)=2.154$, $p=0.98$. There is a large effect size with respect to eta squared value. The chance of finding a significant effect means observed power of the test was found as 0.56. However, ANOVA did not yield significant difference among five treatment groups further analysis could be conducted.

4.3.2 Accuracy

Total task completion accuracy (TTCA) was calculated as percentage of how many tasks were completed successfully over all nine tasks by each participant. Table 4.7 shows descriptive statistics about TTCA and Figure 4.8 shows TTCA vs. treatment.

Table 4.7 Descriptive statistics of TTCA dependent variable

	N	Mean	Std.Dev.	Skewness	Kurtosis
TTCA	34	90.52	13.43	-1.063	-1.48

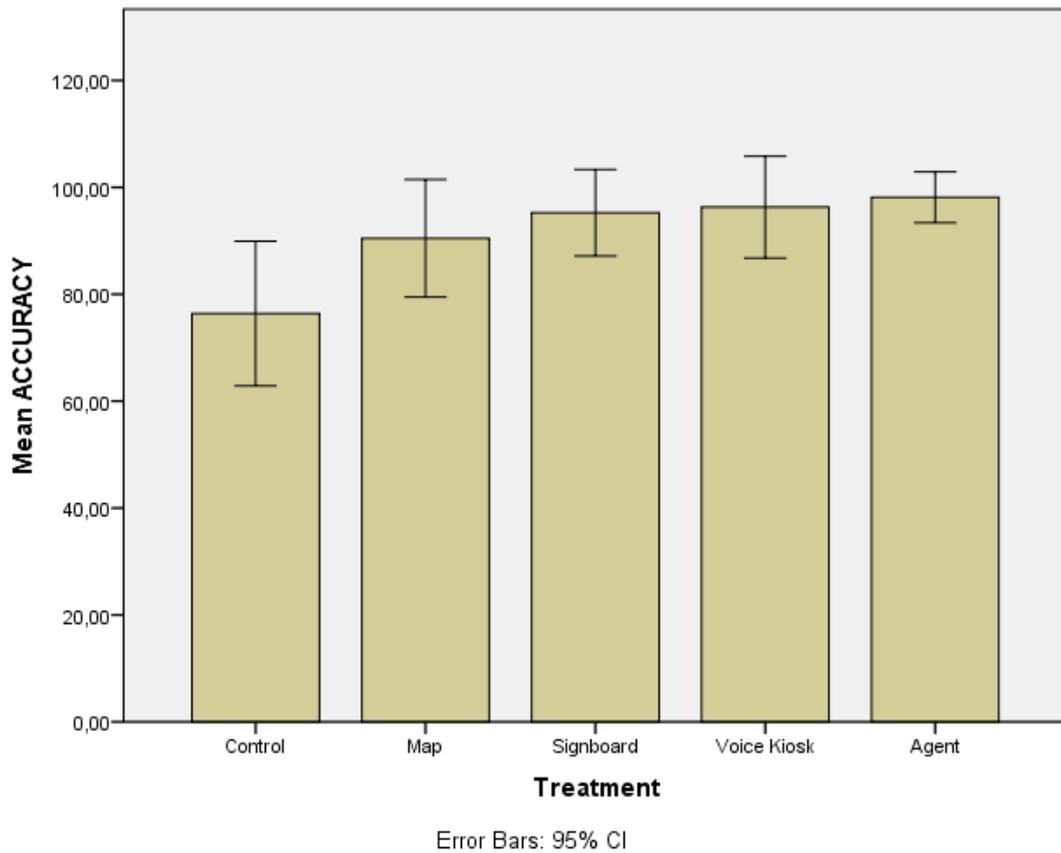


Figure 4.8 Total task completion accuracy for Treatment groups

Figure 4.8 shows that the most agent group completed all tasks successfully %100; on the other hand, control group was the least successful one of all groups with %76.39. To investigate is there significant mean difference between treatment groups in terms of TTCA one-way ANOVA was conducted.

Table 4.8 Levene's test of equality of variances for TTCA dependent variable

	<i>F</i>	df1	df2	<i>p</i>
TTCA	2.951	4	29	0.037

According to Table 4.8 Levene’s test of equality of variances shows significant difference among treatment groups. Therefore correction needs to be made in order to reach conclusive results for following tests.

Table 4.9 ANOVA result with respect to TTCA dependent variable

Source	df	<i>F</i>	<i>p</i>	Eta-Squared	Observed Power
Treatment	4	4.566	0.006	0.386	0.902

According to Table 4.9 there is a significant mean difference between treatment groups in terms of TTCA $F(4,29)=4.566$, $p<0.006$. Moreover, large effect size was found according to eta-squared value to be 0.38 Observed power was strong. Since equality of variances violated Games-Howell test was conducted. Table 4.10 shows that there is a significant mean difference between Control group (C) and Agent group (A) in terms of TTCA.

Table 4.10 Games-Howell test result with respect to treatment

	Treatment I	Treatment II	Mean Difference	Std.Error	<i>p</i>
Games-Howell	C	A	-21.7593	6.01852	0.038

4.3.3 Time

Each treatment group’s total task completion time (TTCT) was calculated by summing up each task’s completion time in terms of seconds. Descriptive statistics were given in Table 4.11 and TTCT vs. treatment groups graph is shown in Figure 4.8.

Table 4.11 Descriptive statistics of TTCT dependent variable

	N	Mean	Std.Dev.	Skewness	Kurtosis
TTCT	36	1514.93	430.92	0.627	0.036

Figure 4.9 show that the participants in signboard treatment group completed all nine tasks before other groups in 1187.715 seconds. Map group’s participants’ completion of all tasks took the longest time than others in 1931.566 seconds. In order to find out is there a significant difference among treatment groups in terms of TTCT one-way ANOVA was conducted.

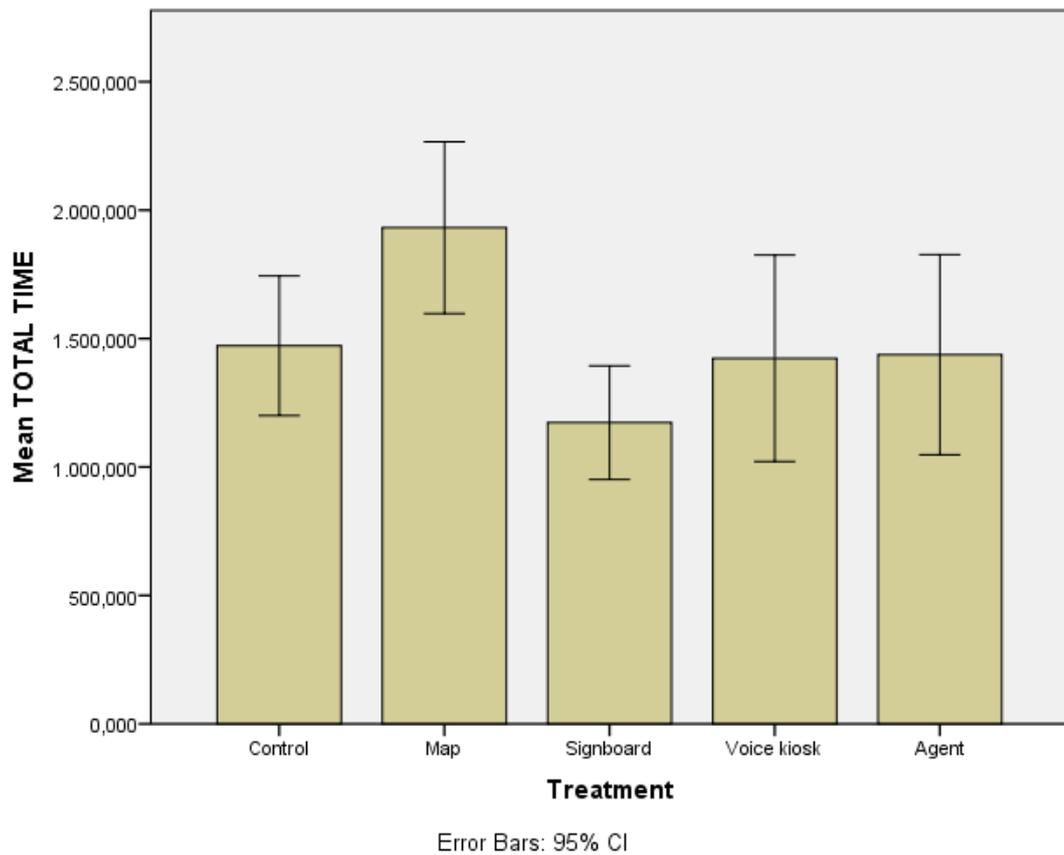


Figure 4.9. Total task completion time for Treatment groups

According to Table 4.12 Leven's test of equality of variances ANOVA's assumption have met. Therefore, there is no need for correction. LSD test reveal whether there is a difference among treatment groups.

Table 4.12 Levene's test of equality of variances TTCT dependent variable

	<i>F</i>	df1	df2	<i>p</i>
TTCT	1.744	4	31	0.165

Table 4.13 ANOVA result with respect to TTCT dependent variable

Source	df	<i>F</i>	<i>p</i>	Eta-Squared	Observed Power
Treatment	4	4.786	0.004	0.382	0.919

With respect to Table 4.13 at least one treatment groups different from others in terms of TTCT $F(4,31)=4.147$, $p=0.008$. There is a large effect size with respect to eta-squared value. In fact this value indicates that 38.2% of the univariate variance of the dependent variable was associated with the treatment. Moreover, observed power was found 0.919. To find out which treatment groups differs from others in terms of TTCT LSD test was conducted. According to Table 4.14 revealed that there is a significant mean difference between map group (M) and control group (C), signboard group (S), voice group (V), agent group (A). However, there was no significant mean difference among (C), (S), (V) and (A) in terms of TTCT.

Table 4.14 LSD test result with respect to treatment

	Treatment -I	Treatment-II	Mean Difference	Std.Error	<i>p</i>
LSD	M	C	-459.221	174.937	0.013
		S	758.454	181.432	0.000
		V	508.278	189.746	0.012
		A	494.398	189.746	0.014

A one-way repeated measures ANOVA was conducted to compare the effect of treatment on task completion time (TCT) in nine different tasks. Table 4.15 shows descriptive statistics conducted TCT dependent variables.

Table 4.15 Descriptive statistics of all TCT dependent variables

	N	Mean	Std.Dev.	Skewness	Kurtosis
TCT-1	36	192.87	185.89	2.212	5.646
TCT-2	36	123.99	139.56	3.342	13.305
TCT-3	36	119.56	134.67	1.611	1.590
TCT-4	36	24.,4	143.3	1.572	2.730
TCT-5	36	45.34	17.93	1.272	1.039
TCT-6	36	86.99	35.3	1.673	2.940
TCT-7	36	148.61	67.84	0.583	0.212
TCT-8	36	170.62	55.93	1.596	3.441
TCT-9	36	160.95	72.78	2.205	6.616

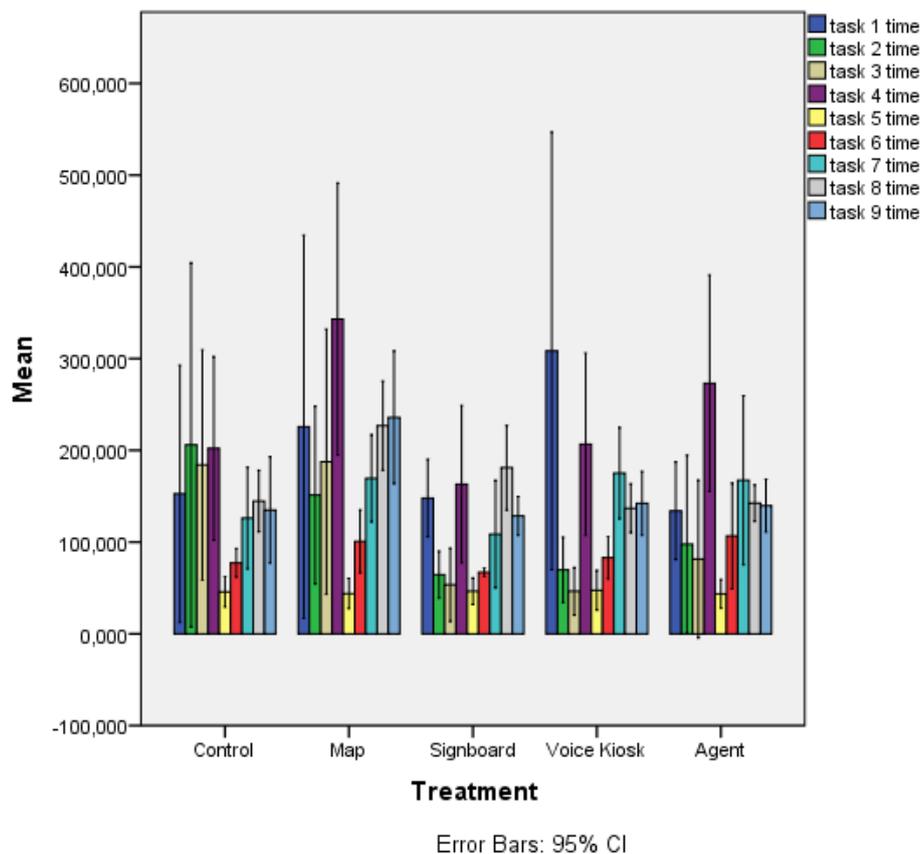


Figure 4.10 Task completion time for 9 tasks for each Treatment groups

Figure 4.10 shows that the task completed in the shortest time in all treatment groups is task-5. The participants in control group needed 45.519 seconds, the participants in map group required 43.884 seconds, signboard group's participants needed 46.479 seconds, voice group's participants needed 47.427 seconds and agent group required 43.619 seconds to complete task-5 averagely. However, the task required the longest time differs between groups. Control group completed the task-4 in 207.769 seconds averagely with 100% success rate. Map group completed task-4 in 343.138 seconds averagely with 88.9% success rate. Signboard group completed task-4 in 180.984 seconds averagely with 100% success rate. Voice group completed task-4 in 308.526 seconds averagely with 100% success rate. And agent group completed task-4 in 273.132 seconds averagely with 100% success rate.

Table 4.16 shows that Levene's equality of variances for all TCT dependent variables. Task-3 and task-6 showed significant variance difference.

Table 4.16 Levene's test of equality of variances each TCT dependent variable

	<i>F</i>	df1	df2	<i>p</i>
TCT-1	2.476	4	31	0.065
TCT-2	2.230	4	31	0.089
TCT-3	7.999	4	31	0.000
TCT-4	2.083	4	31	0.107
TCT-5	0.230	4	31	0.919
TCT-6	3.772	4	31	0.013
TCT-7	0.268	4	31	0.896
TCT-8	1.098	4	31	0.375
TCT-9	1.198	4	31	0.331

Table 4.17 shows significant difference at $p=0.000$ therefore Greenhouse-Geiser correction was made to reach conclusion.

Table 4.17 Mauchly's test of sphericity for TCT dependent variables

Within Subject Effect	Mauchly's W	Approx. Chi-Square	df	<i>P</i>	Greenhouse-Geiser	Huynh-Feldt	Lower-bound
TCT	0.001	207.765	35	0.000	0.433	0.556	0.125

According to Table 4.18 Greenhouse-Geiser correction showed significant mean difference among task completion time at $F(3.460, 107.271)=10.781$ $p<0.05$. There is a large effect size with respect to partial eta squared value. In fact, 25.8% of the variances of the dependent variables were associated with task completion time. Moreover, observed power is 1.000. Yet, there is no significant interaction effect between treatment and task completion time $F(13.841, 107.271)=1.298$ $p>0.05$.

Table 4.18 one-way repeated measures ANOVA result with respect to TCT dependent variable

Source		df	<i>F</i>	<i>p</i>	Partial Eta Squared	Observed Power
TCT	Greenhouse - Geyser	3.46	10.781	0.000	0.258	1.000
	Lower-bound	1.000	10.781	0.000	0.258	0.889
TCT*TREATMENT	Greenhouse - Geyser	13.481	1.298	0.140	0.143	0.736
	Lower-bound	4.000	1.298	0.292	0.143	0.356

Table 4.19 shows that there is a significant mean difference between TCT-4 and TCT-3 at $M=127.006$ and 95% CI [28.011 – 226.001], TCT-4 and TCT-5 at $M=192.225$, TCT-4 and TCT-6 at $M=150.730$ and CI [79.100 – 222.360], TCT-4 and TCT-7 $M=88.298$ CI [9.502 - 167.094] in terms of task completion time. This result means that the time needed to complete task number 4 was much more than task 3, 5, 6 and 7. According to Table 4.16 TCT-5 row; TCT-5 and TCT-1 $M=-148.343$, CI [-257.148 - 39.538], TCT-5 and TCT-4, TCT-5 and TCT-6, $M=-41.495$

CI [-60.966 - -22.025]; TCT-5 and TCT-7, M=-103.927 CI [-142.396 - -65.457]; TCT-5 and TCT-8, M=-120.945 CI [-150.109 - 91.781]; TCT-5 and TCT-9, M=-110.840 CI [-146.439 - -75.241] have significant mean difference in terms of task completion time. The reason of TCT-5 difference from TCT-1, 4, 6, 7, 8, 9 tasks was due to completion of the mentioned task in shorter time. TCT-6 and TCT-7, M= -62.431 CI [-107.052 - -17.811]; TCT-6 and TCT-8, M=-79.449 CI [-114.555 - -44.344]; TCT-6 and TCT-9, M=-69.345 CI [-108.546 - -30.144]; have significant mean difference in terms of task completion time. The reason of TCT-6 difference from TCT-7, 8, 9 tasks was due to completion of the mentioned task in shorter time.

Table 4.19 Pairwise comparison with respect to TCT dependent variable

TCT-I	TCT-J	Mean Difference	Std.Error	<i>p</i>
TCT-4	TCT-3	127.006	28.190	0.003
	TCT-5	192.225	21.488	0.000
	TCT-6	150.730	20.398	0.000
	TCT-7	88.298	22.438	0.016
TCT-5	TCT-1	-148.343	30.984	0.001
	TCT-4	-192.225	21.488	0.000
	TCT-6	-41.495	5.545	0.000
	TCT-7	-103.927	10.955	0.000
	TCT-8	-120.945	8.305	0.000
	TCT-9	-110.84	10.137	0.000
TCT-6	TCT-7	-62.431	12.706	0.001
	TCT-8	-79.449	9.997	0.000
	TCT-9	-69.345	11.163	0.000

4.3.4 Length

Each treatment group's total task completion length (TTCL) was calculated by summing up each task's completion length. It can be seen in Appendix-J treatment groups followed path in the environment Descriptive statistics were given in Table 4.17 and TTCL vs. treatment groups graph is shown in Figure 4.11.

Table 4.20 Descriptive statistics of TTCL dependent variable

	N	Mean	Std.Dev.	Skewness	Kurtosis
TTCL	36	298.09	81.58	0.683	-0.238

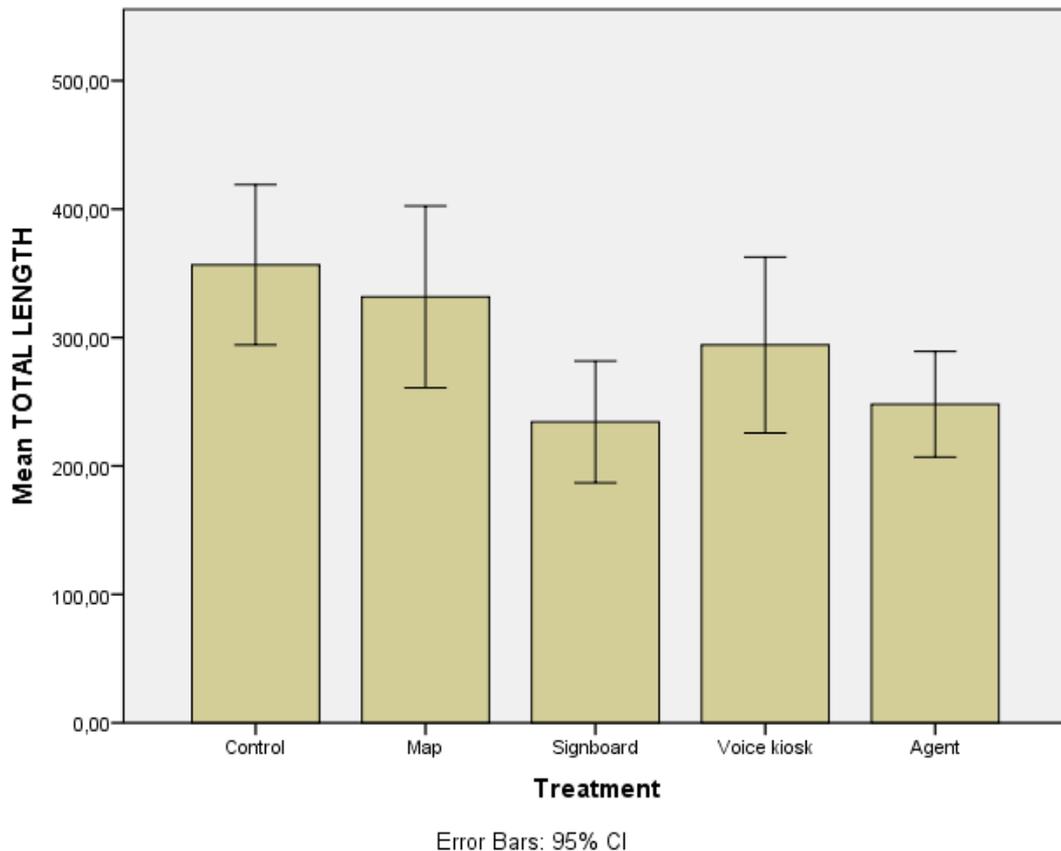


Figure 4.11. Total task completion length for Treatment groups

Figure 4.11 shows that the participants in the signboard group completed tasks before all other groups.in 234.28 meter averagely. The least successful group was control group , the participants were completed all tasks in 331.68 meter averagely. In order to find out is there a significant difference among treatment groups in terms of TTCT one-way ANOVA was conducted. According to Table 4.21 one-way ANOVA's

equality of variances met since $p > 0.05$ at Levene's test of equality of variances for TTCL.

Table 4.21 Levene's test of equality of variances for TTCL dependent variable

	<i>F</i>	df1	df2	<i>P</i>
TTCL	1.570	4	31	0.207

According to Table 4.22 at least one of the treatment groups is different in terms of TTCL $F(4, 31) = 4.147$ $p < 0.05$. There is a large effect size with respect to eta-squared value. In fact this value indicates that 34.9% of the univariate variance of the dependent variable was associated with the treatment. Moreover, observed power was found 0.873. To find out which treatment groups are different from others in terms of TTCL LSD test was conducted.

Table 4.22 ANOVA result with respect to dependent variable of TTCL

Source	df	<i>F</i>	<i>p</i>	Partial Eta-Squared	Observed Power
Treatment	4	4.147	0.008	0.349	0.873

According to Table 4.23 revealed that there is a significant mean difference between control group (C) and signboard group (S), control group (C) and agent group (A). And also, map group (M) and signboard group (S), map group (M) and agent group (A). in terms of TTCL.

Table 4.23 LSD test result with respect to treatment

	Treatment I	Treatment II	Mean Difference	Std.Error	<i>p</i>
LSD	C	S	122.351	36.210	0.002
		A	108.607	37.784	0.007
	M	S	97.392	35.258	0.010
		A	83.648	36.873	0.030

A one-way repeated measures ANOVA was conducted to compare the effect of treatment on task completion length (TCL) in nine different tasks.

Table 4.24 Descriptive statistics of all TCL dependent variable

	N	Mean	Std.Dev.	Skewness	Kurtosis
TCL-1	36	37.40	46.38	2.308	5.076
TCL-2	36	28.36	32.75	3.279	12.390
TCL-3	36	26.81	33.72	1.901	2.697
TCL-4	36	53.76	27.16	1.239	0.757
TCL-5	36	11.45	3.12	1.049	0.315
TCL-6	36	23.16	4.43	2.268	5.633
TCL-7	36	34.30	18.02	0.413	-1.042
TCL-8	36	45.09	9.55	0.926	0.936
TCL-9	36	37.76	9.35	2.281	6.251

Figure 4.12 shows that the task completion length. According to the figure, task- 5 had the shortest length in all treatment groups. However, the task required the longest length differs between groups. The participants in control group needed 54.80 meters, the participants in map group required 66.62 and agent group's participants needed 55.72 meters to complete task-4 averagely. Signboard group completed the task-8 in 51.51 meters averagely. Voice group completed task-1 in 61.22 meters averagely.

Table 4.25 Levene's test of equality of variances for each TCL dependent variable

	<i>F</i>	df1	df2	<i>p</i>
TCL-1	2.616	4	31	0.054
TCL-2	2.855	4	31	0.040
TCL-3	7.846	4	31	0.000
TCL-4	4.088	4	31	0.009
TCL-5	0.192	4	31	0.941
TCL-6	2.136	4	31	0.100
TCL-7	0.870	4	31	0.493
TCL-8	1.140	4	31	0.356
TCL-9	1.342	4	31	0.277

According to Levene's test of equality of variances assumption violated by TCL-1, 2, 3, 4 dependent variables, but the remaining TCL variables met the assumption. In any case the corrected model was used to reach conclusive results during one-way repeated ANOVA.

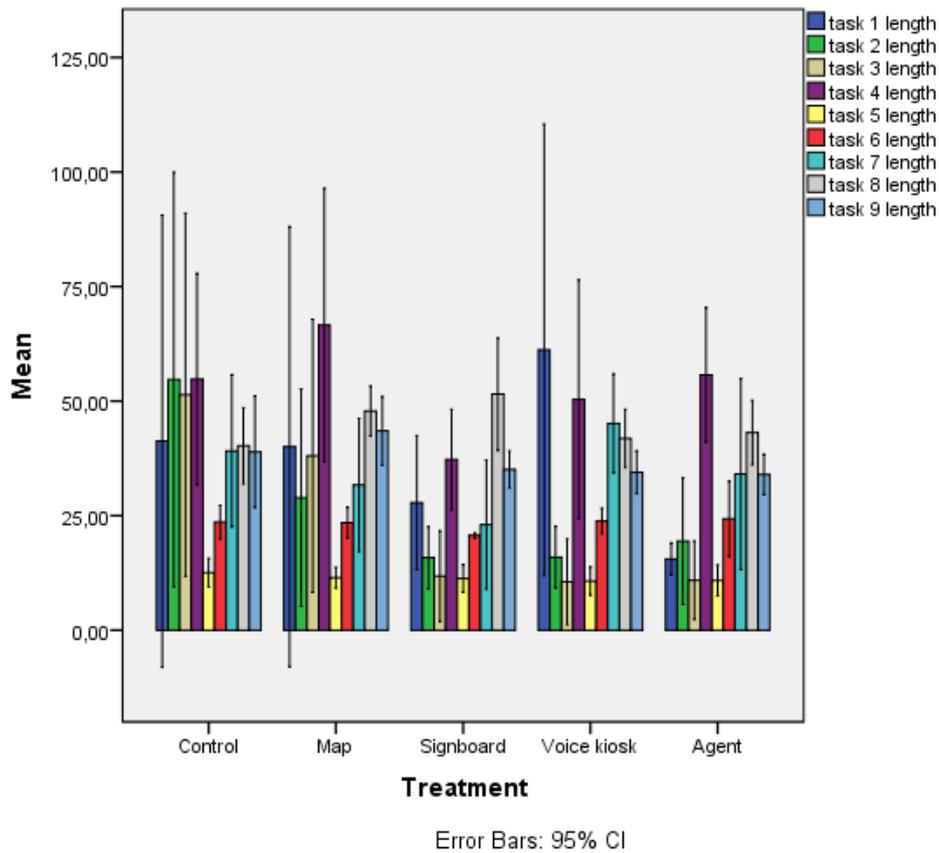


Figure 4.12. Total task completion time for 9 tasks for Treatment groups

With respect to Table 4.26 sphericity assumption of one-way repeated measures ANOVA violated. Therefore, Greenhouse-Geiser correction was used and sphericity assumption was met $p > 0.05$.

Table 4.26 Mauchly's test of sphericity for TCL

Within Subject Effect	Mauchly's W	Approx. Chi-Square	df	<i>p</i>	Greenhouse - Geiser	Huynh-Feldt	Lower-bound
TCL	0	254.952	35	0.000	0.409	0.521	0.125

According to Table 4.27, Greenhouse-Geiser correction showed significant mean difference among task completion length at $F(3.268, 101.313)=9.184$ $p=0.000$. There is a large effect size with respect to partial eta squared value. In fact, 22.9% of the variances of the dependent variables were associated with task completion time. Moreover, observed power is 0.997. Yet, there is no significant interaction effect between treatment and task completion time $F(13.073, 101.313)=1.223$ $p>0.05$.

Table 4.27 Test of within subjects effects for TCL dependent variable

Source		df	<i>F</i>	<i>p</i>	Partial Eta Squared	Observed Power
TCL	Greenhouse - Geiser	3	9.184	0.000	0.229	0.997
	Lower-bound	1.000	9.184	0.005	0.229	0.835
TCL*TREATMENT	Greenhouse - Geiser	13.073	1.223	0.274	0.136	0.683
	Lower-bound	4.000	1.223	0.321	0.136	0.337

With respect to Table 4.28, indicating that there was a significantly mean difference between treatment groups with in terms of these nine TCL variables. TCL-4 and TCL-3 $M=28.410$ $CI [6.054 - 50.766]$; TCL-4 and TCL-5 $M=41.578$ $CI [26.013 - 57.142]$; TCL-4 and TCL-6 $M=29.773$ $CI [14.525 - 45.021]$; TCL-4 and TCL-7 $M=18.337$ $CI [0.943 - 35.731]$; TCL-4 and TCL-9 $M=15.760$ $CI [1.246 - 30.275]$ were significantly different. The reason of TCL-4 difference from TCL-3, 5, 6, 7, 9 tasks was due to completion of the mentioned task in longer length. TCL-5 and TCL-6 $M= -11.805$ $CI [-14.573 - -9.037]$; TCL-5 and TCL-7 $M=-23.241$ $CI [-33.545 - -12.936]$; TCL-5 and TCL-8 $M=-33.543$ $CI [-39.139 - -27.947]$; TCL-5 and TCL-9 $M=-25.818$ $CI [-30.795 - -20.840]$ were significantly different from each other. The reason of TCL-5 difference from TCL-6, 7, 8, 9 tasks was due to completion of the mentioned task in shorter length. TCL-6 and TCL7 $M=-11.436$ $CI[-22.429 - -0.443]$;TCL-6 and TCL8 $M=-21.738$ $CI[-28.095 - -15.381]$; TCL-6 and TCL9 $M=-$

14.012 CI[-19.429 - -8.596] were significantly different. The reason of TCL-6 difference from TCL-7, 8, 9 tasks was due to completion of the mentioned task in shorter length. TCL-8 and TCL-3 M=20.375 CI [2.414 – 38.336]; TCL-8 and TCL-9 M=7.725 CI [0.417 – 15.034] were significantly different. The reason of TCL-8 difference from TCL-3, 9 tasks was due to completion of the mentioned task in longer length.

Table 4.28 Pairwise comparison for TCL dependent variable

TCL-I	TCL-J	Mean Difference	Std.Error	<i>P</i>
TCL-4	TCL-3	28.410	6.366	0.004
	TCL-5	41.578	4.432	0.000
	TCL-6	29.773	4.432	0.000
	TCL-7	18.337	4.953	0.030
	TCL-9	15.760	4.133	0.022
TCL-5	TCL-6	-11.805	0.788	0.000
	TCL-7	-23.241	2.934	0.000
	TCL-8	-33.543	1.593	0.000
	TCL-9	-25.818	1.417	0.000
TCL-6	TCL-7	-11.436	3.13	0.034
	TCL-8	-21.738	1.81	0.000
	TCL-9	-14.012	1.542	0.000
TCL-8	TCL-3	20.375	5.115	0.014
	TCL-9	7.725	2.081	0.029

4.3.5 Standard Signboard

Each treatment group's total standard signboard gaze duration (TSSGD) was calculated by summing up each task's standard signboard completion duration (SSGD). Descriptive statistics were given in Table 4.29 and TSSGD vs. treatment groups graph is shown in Figure 4.11.

Table 4.29 Descriptive statistics of TSSGD dependent variable

	N	Mean	Std.Dev.	Skewness	Kurtosis
TSSGD	31	89.862	36.908	0.406	0.407

According to Figure 4.13 map group’s participants’ TSSGD was shortest among other groups with 59.804 seconds averagely. However, control group looked at standard sign boards more than other group’s participants with 114.796 seconds averagely. The reason of control group’s high TSSGD scores was due to not presenting of way finding cues. To discover whether there is a significant mean difference between treatment groups in terms of TSSGD one-way ANOVA was conducted.

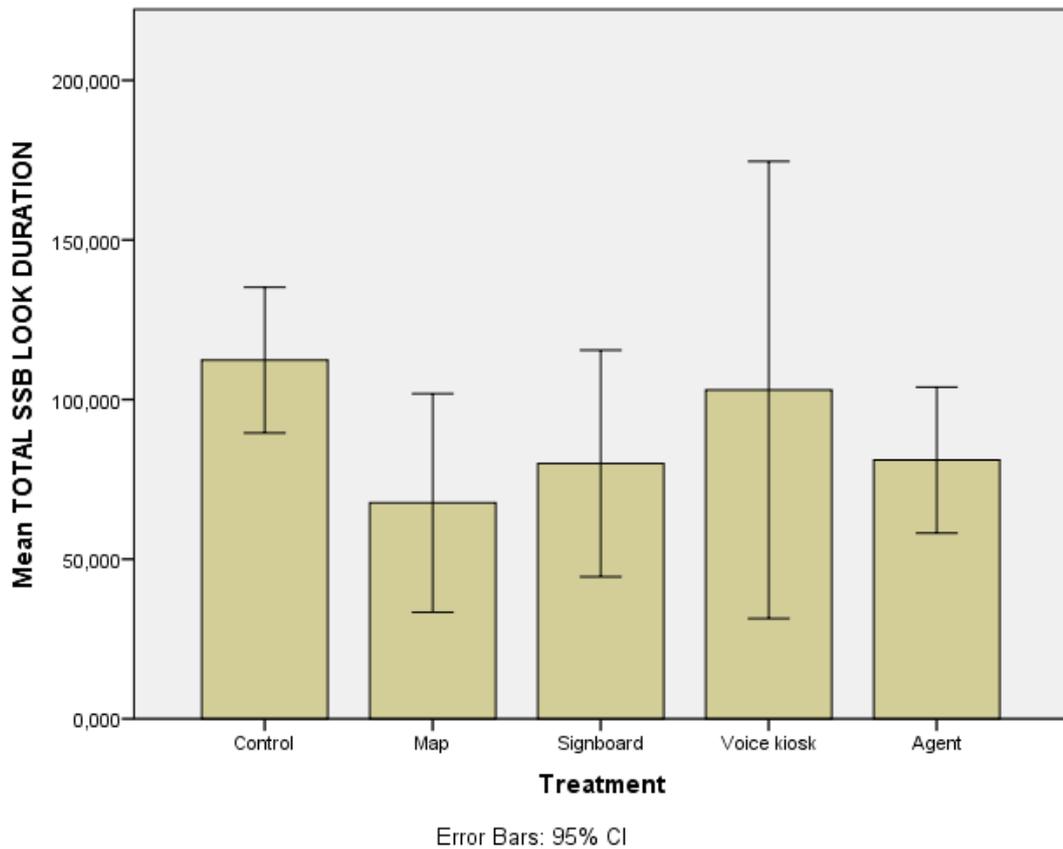


Figure 4.13 Total standard sign board look duration for Treatment groups

According to Table 4.30 Levene's test of equality of variances revealed that there was no significant difference between variances. Moreover, one-way ANOVA assumption met.

Table 4.30 Levene's test of equality of variances of TSSGD dependent variable

	<i>F</i>	df1	df2	<i>p</i>
TSSGD	0.940	4	26	0.456

According to Table 4.31 any treatment groups is different in terms of TSSGD $F(4, 26)=1.817$ $p>0.05$. Therefore there was no need for further analysis in one-way ANOVA test. However, to investigate if there is a significant difference between treatment groups in terms of each SSGD variables one-way repeated measures ANOVA was conducted.

Table 4.31 ANOVA result with respect to dependent variable of TSSGD

Source	df	<i>F</i>	<i>P</i>	Partial Eta-Squared	Observed Power
Treatment	4	1.817	0.156	0.216	0.476

Table 4.32 shows descriptive statistics for nine SSGD dependent variables.

Table 4.32 Descriptive statistics for each SSGD dependent variables

	N	Mean	Std.Dev.	Skewness	Kurtosis
SSGD-1	31	13.931	15.808	2.143	5.431
SSGD-2	31	8.662	11.788	3.168	11.611
SSGD-3	31	6.158	5.651	1.535	2.060
SSGD-4	31	11.128	10.673	2.820	10.845
SSGD-5	31	1.584	2.276	3.423	14.419
SSGD-6	31	3.271	5.246	4.515	22.722
SSGD-7	31	14.593	9.708	0.954	0.771
SSGD-8	31	17.440	10.654	0.908	1.534
SSGD-9	30	13.532	7.567	0.622	1.263

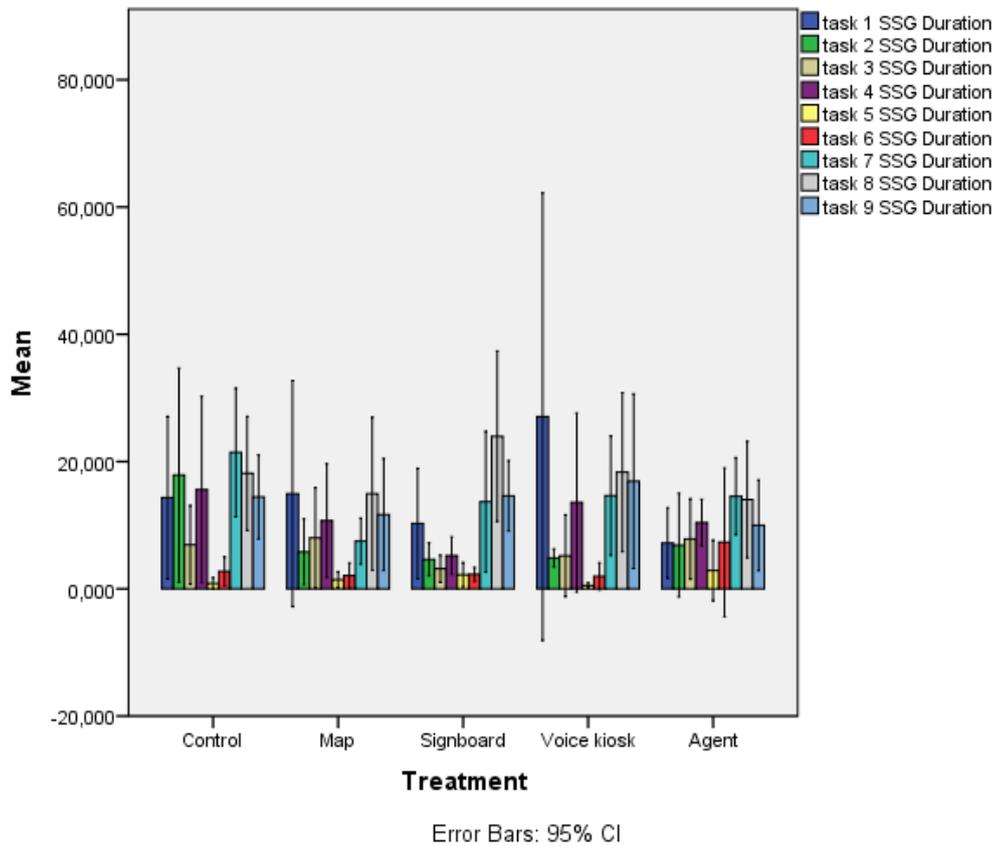


Figure 4.14 Standard sign board look duration for 9 tasks for Treatment groups

With respect to Table 4.33 SSGD-2, SSGD-5 and SSGD-6 violated equality of variances of one-way repeated measures ANOVA. Thus, to reach conclusive results Greenhouse-Geiser correction was made.

Table 4.33 Levene's test of equality of variances for each SSGD dependent variable

	<i>F</i>	df1	df2	<i>p</i>
SSGD-1	2.534	4	25	0.65
SSGD-2	4.714	4	25	0.006
SSGD-3	0.957	4	25	0.448
SSGD-4	1.389	4	25	0.266
SSGD-5	3.160	4	25	0.031
SSGD-6	3.528	4	25	0.020
SSGD-7	1.749	4	25	0.171
SSGD-8	0.224	4	25	0.923
SSGD-9	0.391	4	25	0.813

According to Table 4.34 Greenhouse-Geiser correction one-way repeated measures ANOVA assumption was met at $p>0.05$.

Table 4.34 Mauchly's test of sphericity for SSGD

Within Subject Effect	Mauchly's W	Approx. Chi-Square	df	<i>p</i>	Greenhouse - Geiser	Huynh-Feldt	Lower-bound
SSGD	0.028	78.727	35	0.000	0.582	0.846	0.125

With respect to Table 4.35 at least one treatment groups different from others in terms of SSGD $F(4.656, 116.397)=10.725, p=0.000$. There is a large effect size with respect to eta-squared value. In fact this value indicates that 30.0% of the univariate variance of the dependent variable was associated with the treatment. Moreover, observed power was found 1.000. Yet, there was no significant interaction between SSGD and treatment groups.

Table 4.35 Test of within subjects effects for SSGD and treatment

Source		df	<i>F</i>	<i>p</i>	Partial Eta Squared	Observed Power
SSGD	Greenhouse-Geiser	8	10.725	0.000	0.300	1.000
	Lower-bound	1.000	10.725	0.003	0.300	0.882
SSGD*TREATMENT	Greenhouse-Geiser	18.623	1.164	0.301	0.157	0.925
	Lower-bound	4.000	1.164	0.350	0.157	0.311

To reveal that which SSGD variables were different from other pairwise comparison tests conducted. With respect to Table 4.37 SSGD-1 and SSGD-5, $M=13.170$ CI [2.668 – 23.673]; SSGD-1 and SSGD-5, $M= 11.479$ CI [0.753 – 22.205], were significantly different. This result indicates that participants in all groups looked at

standard signboards in the first task more than task5 and task6. SSGD-3 and SSGD-5, M= CI[];SSGD-3 and SSGD-5, M=4.624 CI [0.274 – 8.974]; SSGD-3 and SSGD-7, M= -8.140 CI [-15.711 - -0.569]; SSGD-3 and SSGD-8, M= -16.293 CI[-19.892 - -3.446]; SSGD-3 and SSGD-9, M= -11.935 CI [-13.084 - -1.538] were significantly different. This results shows that participants in all groups looked at standard signboards in task-3 less than task-7,8,9 but SSGD in task-5 was less than task-3's SSGD. SSGD-5 and SSGD-4, M= -9.513 CI [-16.620 - -2.407]; SSGD-5 and SSGD-7, M= -12.764 CI [-18.731 - -6.798]; SSGD-5 and SSGD-8, M= -16.293 CI [-23.069 - -9.518]; SSGD-5 and SSGD-9, M= -11.935 CI [-17.164 - -6.707] were significantly different. This result indicates that all of the participants looked at standard signboards less than SSGD-4, 7, 8, 9. Moreover, SSGD-6 and SSGD-7, M= -11.073 CI [-17.164 - -3.996]; SSGD-6 and SSGD-8, M= -14.602 CI [-22.870 - -6.334]; SSGD-6 and SSGD-7, M= -10.244 CI[-17.099 - -3.389] were significantly different. This result indicates that SSGD-6 was significantly less than SSGD-7, 8, 9.

Table 4.36 Pairwise comparison for SSGD dependent variables

TCT-I	TCT-J	Mean Difference	Std.Error	<i>p</i>
SSGD-1	SSGD-5	13.170	2.921	0.005
	SSGD-6	11.479	2.983	0.026
SSGD-3	SSGD-5	4.624	1.210	0.028
	SSGD-7	-8.140	2.106	0.025
	SSGD-8	-11.669	2.287	0.001
	SSGD-9	-7.311	1.606	0.004
SSGD-5	SSGD-4	-9.513	1.977	0.005
	SSGD-7	-12.764	1.660	0.000
	SSGD-8	-16.293	1.884	0.000
	SSGD-9	-11.935	1.454	0.000
SSGD-6	SSGD-7	-11.073	1.968	0.000
	SSGD-8	-14.602	2.300	0.000
	SSGD-9	-10.244	1.907	0.001

Since, one-way repeated measures ANOVA did not yield significant difference among treatment groups at $p < 0.05$ further analysis could not be conducted.

4.3.6 Navigation Cue Gaze Duration

Each treatment group's total navigation cue gaze duration (TNCGD) was calculated by summing up each task's navigation cue duration (NCGD). Descriptive statistics were given in Table 4.37 and TNCGD vs. treatment groups graph is shown in Figure 4.15.

Table 4.37 Descriptive statistics of TNCGD dependent variable

	N	Mean	Std.Dev.	Skewness	Kurtosis
TNCGD	23	193.78	139.417	1.562	1.930

Since there was no navigation cue on control group in this section control group's data excluded in this analysis procedure. According to Figure 4.15 map group's participants' TNCGD was longest among other groups with 364.200 seconds averagely. However, signboard group looked at navigation cues shorter than other group's participants with 120.845 seconds averagely. To discover whether there is a significant mean difference between treatment groups in terms of TNCGD one-way ANOVA was conducted.

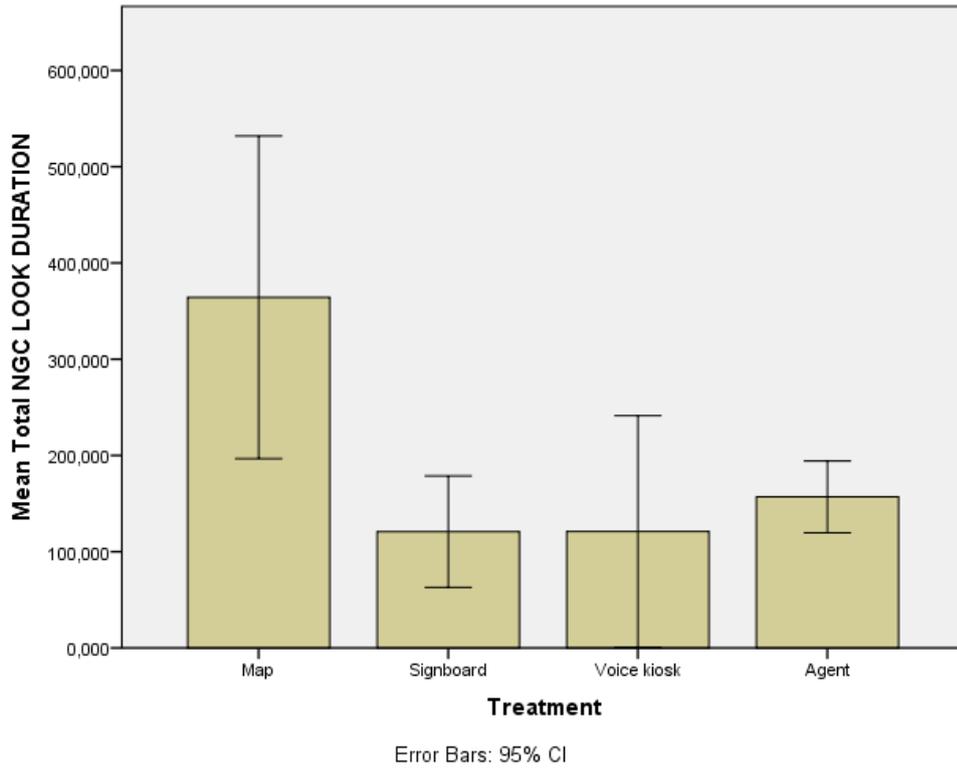


Figure 4.15 Total navigation cue look duration for Treatment groups

With respect to Table 4.38 one-way ANOVA’s equality of variances violated because of Levene’s test of equality of variances was found significant. Therefore a correction needed to be made to get conclusive results from this analysis.

Table 4.38 Levene’s test of equality of variances for TNGCD dependent variable

	<i>F</i>	df1	df2	<i>p</i>
TNGCD	6.599	3	19	0.003

With respect to Table 4.39 at least one treatment groups different from others in terms of TNGCD $F(3,19)=8.165$, $p=0.001$. There is a large effect size with respect to eta-squared value. In fact this value indicates that 56.3% of the univariate variance of the dependent variable was associated with the treatment. Moreover, observed power

was found 0.974. To find out which treatment groups differs from others in terms of TNGCD Games-Howell test was conducted.

Table 4.39 ANOVA result with respect to dependent variable of TNGCD

Source	df	<i>F</i>	<i>p</i>	Partial Eta-Squared	Observed Power
Treatment	3	8.165	0.001	0.563	0.974

According to Table 4.40 Games-Howell revealed that there is a significant mean difference between map group (M) and signboard group (S), in terms of TNGCD.

Table 4.40 Games-Howell test result with respect to treatment

	Treatment I	Treatment II	Mean Difference	Std.Error	<i>p</i>
Games-Howell	M	S	243.356	69.000	0.045

A one-way repeated measures ANOVA was conducted to compare the effect of treatment on navigation cue gaze duration (NCGD) in nine different tasks. Table 4.41 shows descriptive statistics conducted NCGD dependent variables descriptive statistics.

Table 3.41 Descriptive statistics of NCGD dependent variable

	N	Mean	Std.Dev.	Skewness	Kurtosis
NCGD-1	23	51,047	55,560	2,761	8,640
NCGD-2	23	13,260	12,314	0,779	-0,470
NCGD-3	23	14,229	28,680	3,665	14,876
NCGD-4	23	41,625	49,228	2,841	10,081
NCGD-5	23	1,778	5,834	4,503	20,930
NCGD-6	23	16,276	22,085	2,888	10,287
NCGD-7	23	27,970	22,585	1,326	1,499
NCGD-8	23	15,936	13,723	1,697	4,014
NCGD-9	22	12,184	13,060	1,270	1,153

According to Figure 4.26 participants in map group look navigation cue more than other groups especially task-4 with 86.428 seconds averagely. Sign group's participants looked navigation cues especially in task-1 more than other tasks with 32.351 second averagely. Moreover, voice group's participant's gaze duration in task-1 was also higher than other tasks in their group with 55.223 second averagely. Agent group's task-4 gaze duration also was higher than other tasks gaze duration on navigation cues. With 41.510 seconds. On the other hand, in all treatment groups' participations' gaze duration were less than 5 seconds in tas-5. Due to the task-5 took place inside media center building with almost no navigation cues.

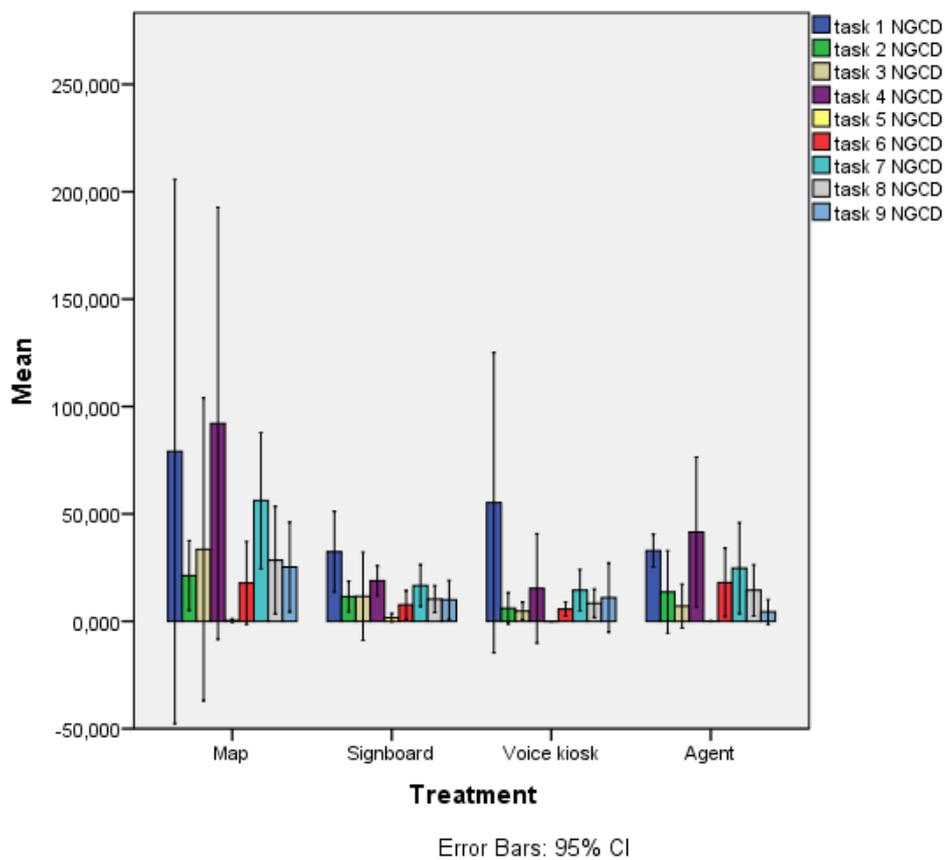


Figure 4.16 Total navigation cue look duration for 9 tasks for Treatment groups

Table 4.42 shows that except for NCGD-9 all NCGD dependent variables violates Levene's test of equality of variances. Therefore, correction needed to utilize for

reaching conclusive results. With respect to Table 4.41 at least one treatment groups different from others in terms of NCGD $F(2.228, 40.100)=7.935, p=0.001$. Moreover, according to Table 4.44 there is a large effect size with respect to eta-squared value. In fact this value indicates that 30.6% of the univariate variance of the dependent variable was associated with the treatment. Moreover, observed power was found 0.955 Yet, there was no significant interaction between treatment groups and NCGD.

Table 4.42 Levene's test of equality of variances

	<i>F</i>	df1	df2	<i>p</i>
NGCD-1	3.878	3	18	0.027
NGCD-2	5.407	3	18	0.008
NGCD-3	4.449	3	18	0.017
NGCD-4	3.463	3	18	0.038
NGCD-5	15.803	3	18	0.000
NGCD-6	6.177	3	18	0.004
NGCD-7	6.117	3	18	0.005
NGCD-8	1.938	3	18	0.160
NGCD-9	2.487	3	18	0.093

Table 4.43 Mauchly's test of sphericity for NCGD

Within Subject Effect	Mauchly's W	Approx. Chi-Square	df	<i>p</i>	Greenhouse-Geiser	Huynh-Feldt	Lower-bound
NCGD	0.000	150.890	35	0.000	0.278	0.373	0.125

Table 4.44 Test of within subjects effects of NCGD, treatment

Source		df	<i>F</i>	<i>p</i>	Partial Eta Squared	Observed Power
NCGD	Greenhouse-Geiser	2.228	7.935	0.001	0.306	0.955
	Lower-bound	1.005	7.935	0.011	0.306	0.759
NCGD*TREATMENT	Greenhouse-Geiser	6.683	1.076	0.395	0.152	0.393
	Lower-bound	3.000	1.076	0.384	0.152	0.243

Moreover, Table 4.45 indicates that there is a significant mean difference among treatment groups in terms of NCGD dependent variables. NCGD-4 and NCGD-3 $M=27.732$ CI [2.698 – 52.765]; NCGD-4 and NCGD-5 $M=41.405$ CI [6.330 – 76.479] were significantly different. This results means that participants looked more navigation cues in task-4 than task-3 and task-5. NCGD-5 and NCGD-1 $M=-49.342$ CI [-94.250 - -4.435]; NCGD-5 and NCGD-2. $M=-12.609$ CI [-22.605 - -2.612]; NCGD-5 and NCGD-6 $M=-11.777$ CI [-21.068 - -2.487]; NCGD-5 and NCGD-7 $M=-27.481$ CI [-41.487 - -13.474]; NCGD-5 and NCGD-8 $M=-14.858$ CI [-24.392 - -5.323]; NCGD-5 and NCGD-9 $M=-12.129$ CI [-21.150 - -3.107] were significantly different. This result indicates that participants looked on navigation cues during task-5 less than task-1, 2, 6, 7, 8, and 9. NCGD-6 and NCGD-7 $M=-15.703$ CI [-30.187 - -1.219] means participants looked less on navigation cues during task-6 than task-7. Moreover, NCGD-7 and NCGD-9 $M=15.352$ CI [0.324 – 30.380] means during task-7 navigation cues was used less than task-7.

Table 4.45 Pairwise comparison test for NCGD dependent variable

Treatment-I	Treatment-J	Mean Difference	Std.Error	<i>p</i>
NCGD-4	NGCD-3	27.732	6.633	0.020
	NGCD-5	41.405	9.293	0.011
NCGD-5	NGCD-1	-49.342	11.898	0.022
	NGCD-2	-12.609	2.649	0.006
	NGCD-6	-11.777	2.462	0.005
	NGCD-7	-27.481	3.711	0.000
	NGCD-8	-14.858	2.526	0.001
	NGCD-9	-12.129	2.390	0.003
NCGD-6	NGCD-7	-15.703	3.838	0.025
NCGD-7	NGCD-9	15.352	3.982	0.042

4.3.7 Workload

Most promising voxels and quantitative data analyses are shown in this section. As it was stated in Chapter 3.12.2 fNIR sensor pad could not be placed all participants fore head due to their physiological differences. Therefore, reliable data could not be gathered from all voxels. After, filtering fNIR data on each voxel as stated in Chapter 3.11.5, it was seen data collected from almost all participants from voxels 2,4,6 located in the left down part of the prefrontal cortex and voxels 12, 14 and 16 located in right down part of the prefrontal cortex. Location of voxell-2, 4 6 12, 14, 16 are shown in Figure 4.17.

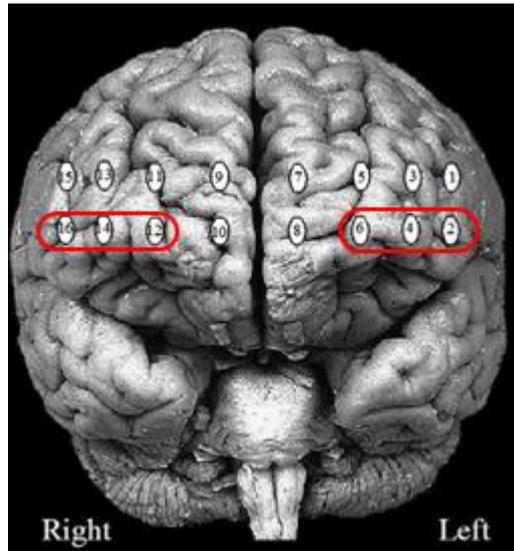


Figure 4.17 Location of voxel-2, 4, 6, 12, 14 and 16

4.3.7.1 Right and Left hemisphere workload

This part of the analysis data collected from voxel-2, 4, 6, 12, 14, and 16 were divided into two. Data gathered from voxel-2, 4, 6 were averaged and named as LEFT AVG. The same process was done for voxel-12, 14, and 16 and resulting data named as RIGHT AVG. In the following sections, one-way ANOVA and one-way repeated measures ANOVA were conducted.

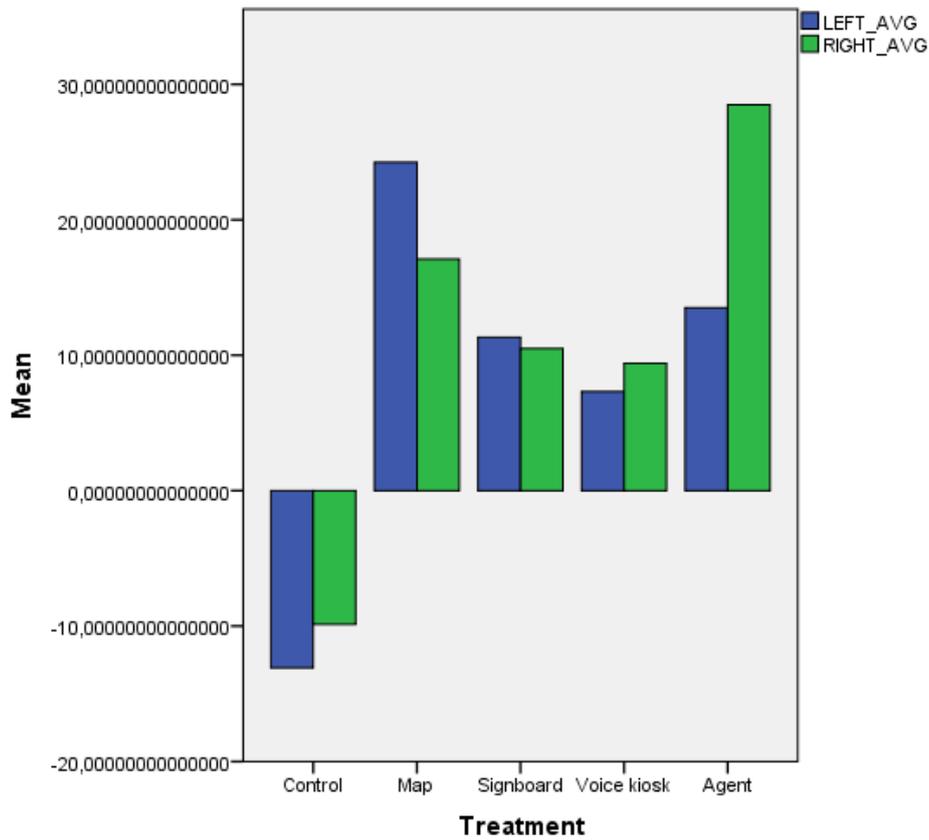


Figure 4.18 Left and right hemisphere’s workload for treatments

It was seen from the Figure 4.18 the participants in map and signboard treatment groups’ left hemisphere’s workload higher than the right hemisphere’s. However, the situation was opposite for voice and agent treatment groups. In fact, in agent group right hemisphere’s workload almost twice as much as left hemisphere’s.

In order to investigate if there is a difference between treatments groups in terms of left hemisphere’s work load one-way ANOVA was conducted. Table 4.46 shows left hemisphere workload average descriptive statistics.

Table 4.46 Descriptive statistics of LHA dependent variable

	N	Mean	Std.Dev.	Skewness	Kurtosis
LHA	35	9.453	18.834	-0.029	-0.611

According to Table 4.47 Leven's test of equality of variances ANOVA's assumption was met at $p > 0.05$. Therefore, there is no need for correction. LSD test reveal whether there is a difference among treatment groups.

Table 4.47 Levene's test of equality of variances for LHA dependent variable

	F	df1	df2	p
LHA	2.031	4	30	0.115

With respect to Table 4.48 at least one treatment groups different from others in terms of LHA $F(4,30)=6.669$, $p=0.001$. There is a large effect size with respect to eta-squared value. In fact this value indicates that 47.1% of the univariate variance of the dependent variable was associated with the treatment. Moreover, observed power was found 0.981.

Table 4.48 ANOVA Results for LHA

Source	df	<i>F</i>	<i>p</i>	Partial Eta-Squared	Observed Power
LHA	4	6.669	0.001	0.471	0.981

To find out which treatment groups differs from others in terms of LHA LSD test was conducted. According to Table 4.49 revealed that there is a significant mean difference between control group (C) and map group (M), signboard group (S), voice group (V), agent group (A). And also, there is a difference in between map group (M) and voice group with respect to LHA at $p < 0.05$.

Table 4.49 LSD test results with respect to LHA

	Treatment -I	Treatment-II	Mean Difference	Std.Error	p
LSD	C	M	-37.334	7.351	0.000
		S	-24.414	7.797	0.004
		V	-20.399	8.116	0.018
		A	-26.589	8.116	0.003
	M	V	16.935	7.688	0.035

The same test was conducted for right hemisphere average workload (RHA). With respect to one-way ANOVA test result there is a significant difference between treatment groups in terms of RHA $F(4,30)=5.271$ $p=0.002$. There is a large effect size with respect to eta-squared value. In fact this value indicates that 41.3% of the univariate variance of the dependent variable was associated with the treatment. Moreover, observed power was found 0.943.

4.3.7.2 Voxel-6 workload

Averaged data collected from voxel-2, 4, 6, 12, 14 and 16 with respect to treatment groups was shown Figure 4.19.

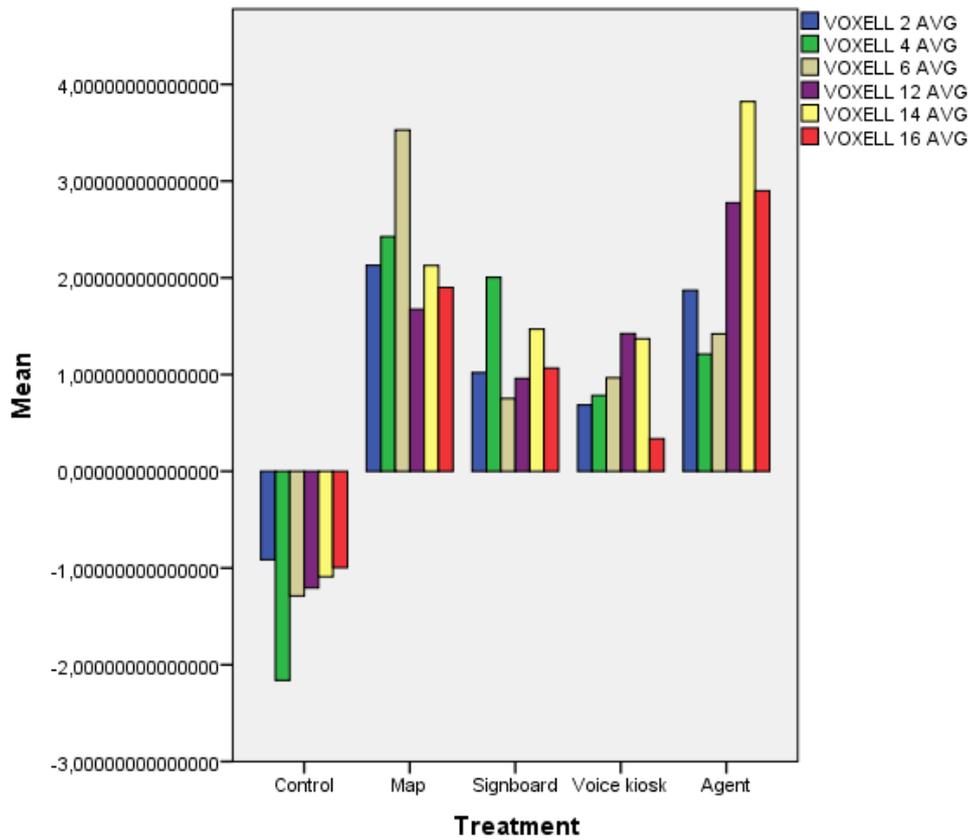


Figure 4.19 Workload values collected from each voxel for each treatment

Map group and agent group’s workload were almost higher in any voxel presented. Results of each voxel showed the same trend of increase and decrease during tasks. In the following section one-way ANOVA and one-way repeated measures ANOVA were conducted to reveal if there is a difference between treatment groups in terms of averaged workload value over 9 tasks and for each task.

Descriptive statistics for V6AVG were shown in Table 4.50

Table 4.50 Descriptive statistics of V6AVG dependent variable

	N	Mean	Std.Dev.	Skewness	Kurtosis
V6AVG	35	1.209	3.339	-0.346	-0.086

According to Table 4.51 Leven’s test of equality of variances ANOVA’s assumption was met at $p>0.05$. Therefore, there is no need for correction. LSD test reveal whether there is a difference among treatment groups in terms of voxel-6 average workload for 9 nine task (V6AVG).

Table 4.51 Levene’s equality of variances test for V6AVG dependent variable

	F	df1	df2	p
V6AVG	1.733	4	30	0.169

With respect to Table 4.52 at least one treatment groups different from others in terms of LHA $F(4,30)=7.667$, $p=0.000$. There is a large effect size with respect to eta-squared value. In fact this value indicates that 50.6% of the univariate variance of the dependent variable was associated with the treatment. Moreover, observed power was found 0.992.

Table 4.52 one-way ANOVA result for V6AVG

Source	df	F	p	Partial Eta-Squared	Observed Power
V6AVG	4	7.677	0.000	0.506	0.992

To find out which treatment groups differs from others in terms of V6AVG LSD test was conducted. According to Table 4.53 revealed that there is a significant mean difference between control group (C) and map group (M), signboard group (S), voice group (V), agent group (A). And also, there is a difference in between map group (M) and signboard groups (S), voice group (V) and agent group (A) with respect to LHA at $p<0.05$.

Table 4.53 LSD test results with respect to V6AVG

	Treatment-I	Treatment-II	Mean Difference	Std.Error	p
LSD	C	M	-4.816	0.882	0.000
		S	-2.039	0.936	0.037
		V	-2.254	0.974	0.028
		A	-2.707	0.974	0.009
	M	S	2.777	0.882	0.004
		V	2.561	0.923	0.009
		A	2.108	0.923	0.030

A one-way repeated measures ANOVA was conducted to compare the effect of treatment on voxel-6 workload (T1V6) in nine different tasks. Table 4.54 shows descriptive statistics conducted V6 dependent variables descriptive statistics. Figure 4.20 shows that all workload values from voxel-6 for all tasks were higher than other treatment groups.

Table 4.54 Descriptive statistics of V6 each dependent variables

	N	Mean	Std.Dev.	Skewness	Kurtosis
V6T1	35	0.9716	1.7021	0.271	-0.427
V6T2	35	0.8727	1.9931	0.114	-0.455
V6T3	35	1.1206	2.3533	0.211	-0.893
V6T4	35	1.0955	2.4382	0.315	0.398
V6T5	35	1.0219	2.7688	0.179	-0.574
V6T6	35	1.0436	2.8318	0.279	-0.637
V6T7	35	1.3830	2.8075	0.584	-0.022
V6T8	35	1.7509	2.6703	0.685	0.827
V6T8	35	1.6247	2.4555	0.649	1.507

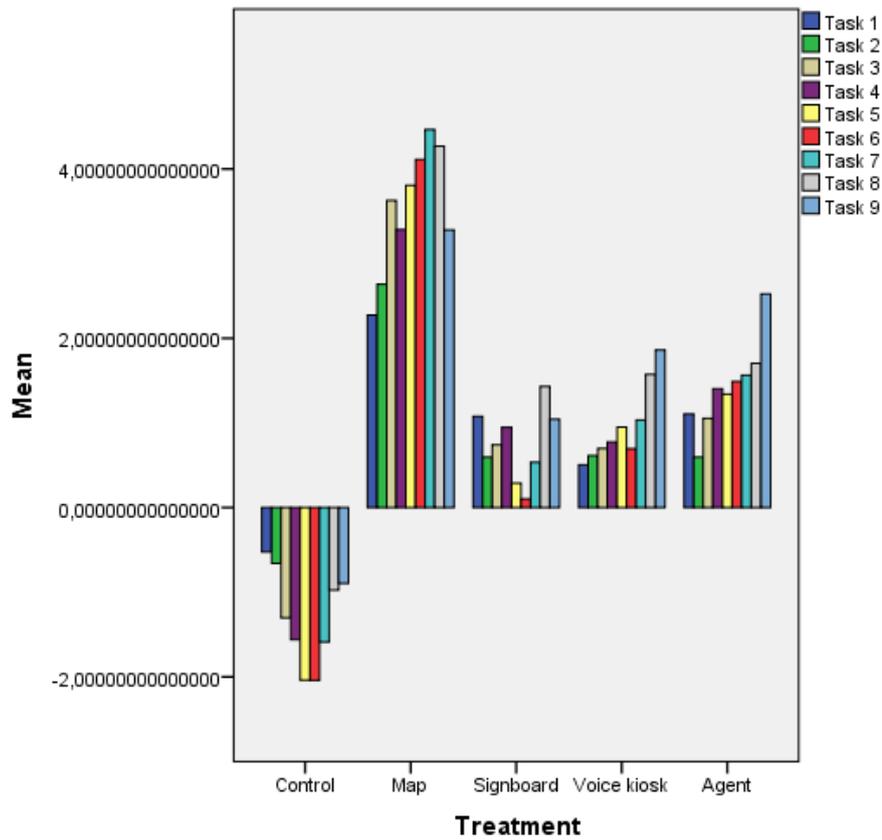


Figure 4.20 Workload average values collected at voxel-6 for each task and treatment

With respect to Table 4.55 only V6T8 dependent variable violates equality of variances assumption. But, remaining variables were met the assumption. Therefore, there was no need for making correction for one-way ANOVA test.

Table 4.55 Levene’s test of equality of variances for each V6 dependent variables

	F	df1	df2	p
V6T1	1.957	4	30	0.127
V6T2	2.025	4	30	0.116
V6T3	1.139	4	30	0.357
V6T4	1.864	4	30	0.143
V6T5	2.110	4	30	0.104
V6T6	1.436	4	30	0.247
V6T7	1.344	4	30	0.277
V6T8	2.698	4	30	0.050
V6T9	0.999	4	30	0.423

Table 4.56 Mauchly's test of sphericity of Voxell-6

Within Subject Effect	Mauchly's W	Approx. Chi-Square	df	<i>p</i>	Greenhouse - Geiser	Huynh-Feldt	Lower-bound
V6	0.005	142.587	35	0,000	0.472	0.620	0.125

With respect to Table 4.56 sphericity assumption of one-way repeated measure ANOVA test, was not met therefore, Greenhouse-Geiser correction was used for reaching conclusive results. According to Table 4.57 at least one treatment groups different from others in terms of V6 $F(3.774, 113.227)=5.923, p=0.000$. Moreover, there is a large effect size with respect to eta-squared value. In fact this value indicates that 16.5% of the univariate variance of the dependent variable was associated with the treatment. Moreover, observed power was found 0.977 Yet, there was no significant interaction between treatment groups and V6.

Table 4.57 One-way repeated measure ANOVA results with respect to V6

Source		df	<i>F</i>	<i>p</i>	Partial Eta Squared	Observed Power
V-6	Greenhouse - Geiser	3.774	5.923	0.000	0.165	0.977
	Lower-bound	1.000	5.923	0.021	0.165	0.654
V-6*TREATMENT	Greenhouse - Geiser	15.097	3.575	0.000	0.323	0.999
	Lower-bound	4.000	3.575	0.017	0.323	0.811

To reveal that which V6 variables were different from others, pairwise comparison tests conducted. With respect to Table 4.58 V6T8 and V6T2, $M=0.200, CI[0.140 - 1.548]$; V6T8 and V6T3, $M=0.173, CI[0.027 - 1.247]$; V6T8 and V6T4, $M= 0.166, CI[0.046 - 1.215]$; V6T8 and V6T5, $M=0.125, CI[0.292 - 1.170]$; V6T8 and V6T6, $M=0.161, CI[0.161 - 1.298]$; were significantly different. These results indicate that workload to complete task-8 was higher than task-2, 3, 4, 5 and 6. Moreover, V6T7

and V6T6, $M= 0.331$, $CI[0.000 - 0.662]$; were significantly different. This result shows that workload to complete task-7 was significantly higher than task-6.

Table 4.58 Pairwise comparisons for V6

TCT-I	TCT-J	Mean Difference	Std.Error	<i>p</i>
V6T8	V6T2	0.844	0.200	0.007
	V6T3	0.637	0.173	0.033
	V6T4	0.631	0.166	0.024
	V6T5	0.731	0.125	0.000
	V6T6	0.730	0.161	0.003
V6T7	V6T6	0.331	0.094	0.050

4.3.7.3 Voxel-16 workload

To investigate if there is significantly mean difference in between treatment groups in terms of workload gathered at voxel-16 one-way repeated ANOVA was conducted. Descriptive statistics of average workload at voxel-16 (V16AVG) is shown Table 4.59.

Table 4.59 Descriptive statistics of V16AVG dependent variable

	N	Mean	Std.Dev.	Skewness	Kurtosis
V16AVG	35	1.057	2.212	-0.368	0.036

According to Table 4.60 Leven's test of equality of variances ANOVA's assumption was met at $p>0.05$. Therefore, there is no need for correction. LSD test reveal whether there is a difference among treatment groups in terms of voxel-6 average workload of 9 nine task (V16AVG).

Table 4.60 Levene's test of equality of variances for V16AVG

	F	df1	df2	<i>p</i>
V16AVG	1.952	4	30	0.127

With respect to Table 4.61 at least one treatment groups different from others in terms of LHA $F(4,30)=4.161$, $p=0.008$. There is a large effect size with respect to eta-squared value. In fact this value indicates that 35.7 % of the univariate variance of the dependent variable was associated with the treatment. Moreover, observed power was found 0.872.

Table 4.61 One-way ANOVA result for V16AVG

Source	df	<i>F</i>	<i>p</i>	Partial Eta-Squared	Observed Power
Treatment	4	4.161	0.008	0.357	0.872

To find out which treatment groups differs from others in terms of V16AVG LSD test was conducted. According to Table 4.62 revealed that there is a significant mean difference between control group (C) and map group (M), signboard group (S), agent group (A). And also, there is a difference in between agent group (A) and voice groups (V) with respect to LHA at $p<0.05$.

Table 4.62 LSD test result with respect to treatment

	Treatment -I	Treatment-II	Mean Difference	Std.Error	<i>p</i>
LSD	C	M	-2.895	0.952	0.005
		S	-2.063	1.009	0.050
		A	-3.895	1.051	0.001
	A	V	2.562	1.090	0.026

A one-way repeated measures ANOVA was conducted to compare the effect of treatment on voxel-6 workload (T1V6) in nine different tasks. Table 4.63 shows descriptive statistics conducted V6 dependent variables descriptive statistics.

Table 4.63 Descriptive statistics of each V16 dependent variable

	N	Mean	Std.Dev.	Skewness	Kurtosis
T1V16	35	0.895	1.837	-0.557	0.327
T2V16	35	0.913	2.000	-0.147	0.394
T3V16	35	0.952	2.216	-0.147	-0.167
T4V16	35	0.904	2.355	-0.227	-0.167
T5V16	35	0.876	2.552	-0.070	-0.079
T6V16	35	0.773	2.404	-0.081	-0.411
T7V16	35	1.119	2.490	-0.204	-0.459
T8V16	35	1.704	2.530	-0.276	-0.007
T9V16	35	1.376	2.463	-0.342	0.017

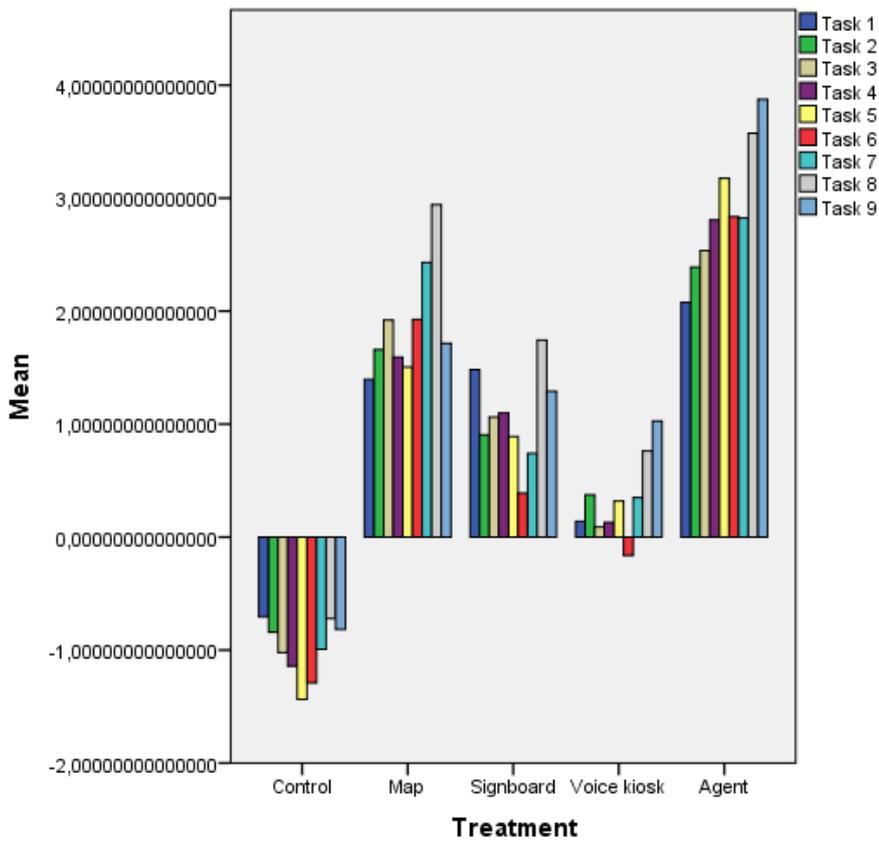


Figure 4.21 Workload average values collected at voxel-16 for each task and treatment

According to Figure 4.21 agent group's participants present higher workload values for all tasks in terms of data gathered voxel-16.

Table 4.64 Levene's test of equality of variances for V16 dependent variables.

	F	df1	df2	p
V16T1	4.023	4	30	0.010
V16T2	1.234	4	30	0.318
V16T3	0.963	4	30	0.442
V16T4	0.866	4	30	0.496
V16T5	2.414	4	30	0.071
V16T6	1.956	4	30	0.127
V16T7	0.901	4	30	0.476
V16T8	0.969	4	30	0.439
V16T9	2.436	4	30	0.069

With respect to Table 4.65 only V16T1 dependent variable violates equality of variances assumption. But, remaining variables were met the assumption. Therefore, there was no need for making correction for one-way ANOVA test.

Table 4.65 One-way repeated measure ANOVA results with respect to V16

Within Subject Effect	Mauchly's W	Approx. Chi-Square	df	<i>p</i>	Greenhouse - Geiser	Huynh-Feldt	Lower-bound
V16	0.023	102.374	35	0.000	0.503	0.669	0.125

With respect Table 4.65 sphericity assumption of one-way repeated measure ANOVA test, was not met therefore, Greenhouse-Geiser correction was used for reaching conclusive results. According to Table 4.66 at least one treatment groups different from others in terms of V16 $F(4.207, 134.476)=5.522, p=0.000$. Moreover, there is a large effect size with respect to eta-squared value. In fact this value indicates that 15.5% of the univariate variance of the dependent variable was associated with the treatment. Moreover, observed power was found 0.974 Yet, there was no significant interaction between treatment groups and V16.

Table 4.66 Mauchly's test of sphericity of Voxell-16

Source		df	<i>F</i>	<i>p</i>	Partial Eta Squared	Observed Power
V16	Greenhouse - Geiser	4.027	5.522	0,000	0.155	0.974
	Lower-bound	1,000	5.522	0,026	0.155	0.623
V16*TREATMET	Greenhouse - Geiser	16.108	1.507	0.107	0.167	0.859
	Lower-bound	4,000	1,507	0.225	0.167	0.409

To reveal that which V16 variables were different from others, pairwise comparison tests conducted. With respect to Table 4.64 V16T8 and V6T2, $M=0.763, CI[0.176 - 1.350]$; V6T8 and V6T3, $M=0.743, CI[0.150 - 1.335]$; V6T8 and V6T4, $M= 0.763, CI[0.250 - 1.276]$; V6T8 and V6T5, $M=0.770, CI[0.289 - 1.250]$; V6T8 and V6T6, $M=0.920, CI[0.385 - 1.456]$; V6T8 and V6T7, $M=0.589, CI[0.100 - 1.079]$; were significantly different. These results indicate that workload to complete task-8 was higher than task-2, 3, 4, 5, 6 and 7.

Table 4.67 Pairwise comparisons for V16

TCT-I	TCT-J	Mean Difference	Std.Error	<i>p</i>
V16T8	V16T2	0.763*	0.167	0.003
	V16T3	0.743*	0.168	0.004
	V16T4	0.763*	0.146	0.000
	V16T5	0.770*	0.136	0.000
	V16T6	0.920*	0.152	0.000
	V16T7	0.589*	0.139	0.007

4.3.7 MANOVA Analysis with US, TTCL, TTCT, TSSGD, TTCA Dependent variables

Until this section separate one-way ANOVA and one-way repeated measures ANOVA tests were conducted on different dependent variables in order to search for the significant mean difference among treatment groups in terms of dependent variables. Although this procedure gave important results on treatments for just one dependent variable; it would be useful to investigate treatment groups with respect to select the dependent variables at once. Therefore one-way MANOVA test was conducted. Due to the equality covariance matrices cannot be computed by SPSS 20 when all dependent variables included in to MANOVA, only following dependent variables could be used for MANOVA analysis.

Table 4.68 Levene's test of error variances

	<i>F</i>	df1	df2	<i>p</i>
US	0.281	4	25	0.887
TTCL	1.120	4	25	0.369
TTCT	0.998	4	25	0.427
TSSGD	1.038	4	25	0.407
TTCA	2.765	4	25	0.050

According to Table 4.68 MANOVA's equality of variances assumption was met at $p > 0.05$. Moreover, Box's M test in Table 4.69 also showed that equality of covariance matrices was met.

Table 4.69 Box's M test

Box's M	62.506
F	1107
df1	30
df2	778683
p	0.318

With respect to Table 4.70 there was a significant mean difference between treatment groups with respect to collective dependent variables at $p=0.000$. The multivariate partial eta-squared value based on Wilk's lambda was strong 0.419. This value indicates that 41.9% of multivariate variance of dependent variables was associated with the treatment groups. Moreover, observed power was 0.992. According to these results the difference found between groups comes from treatments.

Table 4.70 MANOVA results with respect to collective dependent variables

Source	Wilks' Lambda	Hypothesis df	Error df	F	p	Partial Eta Squared	Observed Power
Treatment	0.114	20.000	70.599	3.259	0.000	0.419	0.992

According to Table 4.71 TTCL $F(4,25)=4.092$, TTCT $F(4,25)=2.815$ and TTCA $F(4,25)=5.564$ dependent variables were significant at $p<0.05$. However, US and TSSGD were not significant at $p<0.005$.

Table 4.71 Test of between subjects effects for treatment

Source	Dependent Variable	df	F	p	Partial Eta Squared	Observed Power
Treatment	US	4	1.782	0.164	0.222	0.465
	TTCL	4	4.092	0.011	0.396	0.854
	TTCT	4	2.815	0.047	0.311	0.682
	TSSGD	4	1.414	0.258	0.185	0.374
	TTCA	4	5.564	0.002	0.471	0.948

With respect to Table 4.72 in terms of TTCL dependent variable control group and signboard group was significantly different $M=127.547$ CI [7.683 – 233.412] at $p<0.05$. in terms of TTCT dependent variable map group and signboard group was significantly different $M=724.809$ CI [54.177 – 1395.441] at $p<0.05$. Moreover, in terms of TTCA dependent variable control group and map group was significantly different $M=-19.167$ CI [-37.845 – - 0.488] at $p<0.05$; control group and signboard group was significantly different $M=-21.759$ CI [-39.454 – -4.065] at $p<0.05$; control group and voice group was significantly different $M=-19.167$ CI [-37.845 – - 0.488] at $p<0.05$; control group and agent group was significantly different $M=-21.759$ CI [-39.454 – -4.065] at $p<0.05$.

Table 4.72 Pairwise comparisons test for collective dependent variables

Dependent Variable	Treatment-I	Treatment-J	Mean Difference (I-J)	Std. Error	p
TTCL	C	S	120.547	36.666	0.030
TTCT	M	S	724.809	217.865	0.027
TTCA	C	M	-19.167	6.068	0.041
		S	-21.759	5.748	0.009
		V	-19.167	6.068	0.041
		A	-21.759	5.748	0.009

According to Table 4.73 with respect to depended variable US there is a significant mean difference between control group and signboard treatment group at $p < 0.005$. Also, with respect to dependent variable TTCL there is a significant mean difference between control groups and signboard group and also control group and agent group at $p < 0.05$. Moreover, with respect to TTCL there is a significant mean difference between map group and signboard group, and also map group and agent group treatments at $p < 0.05$. Furthermore, with respect to dependent variable TTCT map group and signboard group has a significant mean difference between them at $p < 0.05$, an also there is a significant mean difference between map and agent treatment groups at $p < 0.05$. In addition, dependent variable TTCA there is a significant mean difference between control group and the remaining treatment groups at $p < 0.05$.

Table 4.73 LSD test for collective dependent variables

Dependent Variable	Test	Treatment-I	Treatment-J	Mean Difference (I-J)	Std. Error	p
US	LSD	C	S	-21.3542	8.10201	0.014
TTCL	LSD	C	S	120.5471	36.66578	0.003
			A	108.6071	36.6678	0.007
		M	S	106.5753	41.11054	0.016
			A	94.6353	41.11054	0.030
TTCT	LSD	M	S	724.80910	217.865118	0.003
			V	471.21020	227.552695	0.049
TTCA	LSD	C	M	-19.1667	6.06795	0.004
			S	-21.7593	5.74835	0.001
			V	-19.1667	6.06795	0.004
			A	-21.7593	5.74835	0.001

4.4 Qualitative Data Analysis

An interview is conducted with each participant and data gathered after these interviews are transferred and kept as soft copies.

4.4.1 Question 1: Did you specify any method during tasks?

Control:

Two participants looked at and spent effort to memorize standard signboards. Control group participant 8 stated that “Firstly, I traveled around the environment then followed the standard signboards which were notably helpful”. Control group participant 2 and 7 tried to memorize the paths or routes that were passed through. In addition, control group participant 7 pointed out that trial and error method was required in order to complete tasks because there was no guidance. Two participants stated that they realized the existence of the standard signboards towards the end of the task. Control group participant 9 realized that the colors of the buildings in the environment were matching with the faculty colors in METU.

Map:

Five participants followed maps and standard signboards during tasks. Map group participant 4 stated that she did not have any method at the beginning but began to benefit from maps and standard signboards later. Map group participant 7 declared that she did not also have any method at the beginning but such as map group participant 9, she also responded as “I only used maps”. Map group participant 5 explained that he did not have any method during the tasks and did not ever use maps. He also explained that he realized standard signboards lately and therefore he often got lost.

Signboard:

All signboard group participants agreed on that they used signboards during the tasks. Signboard group participant 6 added that he slightly used signboards.

Voice:

Voice group participant 1 explained that going through main road would be rational. She added that she tried to find out the target destination by listening to kiosks, however, she realized that it was not working. Then she decided to pass through off-road area and used standard signboards. Voice group participant 3 agreed that using voice was leading time loss, instead, she benefited from standard signboards. On the other hand, four participants communicated that they utilized both kiosks and standard signboards.

Agent:

Agent group participant 6 stated that he used agents in order to reach destination and constructed mental pictures of what agents described. Agent group participant 5 stated that “I made predictions mostly and when I did not want to take risk, I received help from agents”. Agent group participant 2 told that she benefited from firstly agents, then standard signboards. Agent group participant 4 utilized from both agents and standard signboards and tried to memorize locations. Agent group participant 1 declared as “I struggled to memorize environment and then asked to agents because asking to agents is more effective than memorizing”. Agent group participant 3 stated that he did not have any method.

4.4.2 Question 2: Which task was the easiest one? What were the reasons for this easiness?

Control:

Two participants explained that the first task was the easiest one and the difficulty of the tasks was increasing. Two participants stated that task 5 was the easiest task because all galleries and cafes were clustered together, thus the target in task 4 and in task 5 were close to each other. Control group participant 3 remarked that all tasks were equal in terms of difficulty. Control group participant 6 explained that Task 8 and 9 were easy because he passed through those target buildings and became familiar with the environment. Control group participant 7 stated that task 2 was the easiest one because the surrounding of target location was open and target was

visible. Control group participant 9 expressed that Task 9 was the easiest because she recognized the target building with the help of the color of the building which matched with faculty colors in METU.

Map:

Three participants explained that Task 6 was the easiest task because they passed through target destination in Task 6 while completing other tasks. Map group participant 1 said “The tasks were easy in general, however, Task 1 which the target was social area was the easiest one. The reason was that the social area was close to me and visible from far away”. Map group participant 2 agreed that Task 1 was the easiest one due to its visibility. Map group participant 7 explained that Task 2 was the easiest because she passed through target in Task 2 during Task 1. Map group participant 2 reported that all tasks were easy. Map group participant 5 showed Task 5 as easiest task since he came around that target earlier and learnt the target location in Task 5. Finally, map group participant 6 responded as “All tasks were easy except from Task 1. I traveled around the environment too much while searching for the target in Task 1. As a result, I became familiar with most of the environment”.

Sign:

Three participants stated that Task 9 was the easiest task because they all passed through earlier. Sign group participant 2 explained Task 2 as the easiest task due to closeness and visibility. Sign group participant 3 told that the initial tasks and Sign group participant 3 told that Task 1 were easy because the targets were close. Sign group participant 7 underlined that final tasks got easy after discovering how to use signboards.

Voice:

Four participants explained that the final tasks were easier than the initial ones because they got used to the environment. Voice group participant 4 stated that Task 2 was the easiest because the target destination was visible due to open surrounding.

Contrarily, Voice group participant 5 considered Task 5 as the easiest because the targets were buildings.

Agent:

Three participants conveyed in the interview that Task 5 was the easiest because they had seen its location during the earlier tasks. Agent group participant 1 stated that the tasks which included agents within the visual field of their avatar were easy. Agent group participant 3 explained that Task 9 was easiest because he memorized the route description that agents had given. Agent group participant 4 reported as “ It was easy to complete Task 6 because it was clearly visible and I passed through that target earlier accidentally”.

4.4.3 Question 3: Which task was the most difficult one? What were the reasons for this difficulty?

Control:

Two participants referred Task 1 as the most difficult task due to the lack of navigator or informative signs. Furthermore, control group participant 3 described the reason why he considers Task 1 as the most difficult task as his effort to associate virtual campus environment with real METU campus site. According to Control Group Participant 4, all tasks were equal in terms of difficulty. He added that in order to finalize tasks fast and accurately, familiarity with the environment and/or maps and signs are required. Control Group Participant 1, Control Group Participant 6, Control Group Participant 2 considered respectively Task 2, Task 8, Task 4 as the most difficult task again due to lack of navigator or informative cues. Control Group Participant 7 found Task 7 as the most difficult and added that actually all tasks incurring faculties were difficult because the buildings were similar to each other and instinctive with regards to appearance.

Map:

Map group participant 1 stated that the tasks far away from the beginning position and especially tasks within the buildings were difficult. Map group participant 2 declared that none of the tasks were difficult. Three of the participants explained that Task 4 was the most difficult one because they interpreted the maps given in a wrong way. Map group participant 8 also described that she interpreted map in a wrong way and as a result, task 3 was the most difficult task. Map group participant 6 said as “Task 1 was the most difficult one, I was not familiar with the environment. Signboards would be used”. Map group participant 3, and 4 showed respectively Task 3 and 7.

Sign:

Three participants stated that Task 8 was the most difficult task, because the entrance was not seen due to trees in the environment. Two participants explained that Task 9 was the most difficult one because it was hard to go through upstairs. Two participants, on the other hand, considered Task 1 as the most difficult because it was the first task and they had difficulties in understanding the task.

Voice:

Five participants stated that they had difficulties in the first tasks because they were not familiar with the environment. They also pointed out that they did not need to listen to kiosks after listening once because they were incurring time loss. Voice group participant 4 considered Task 7 as the most difficult because he has forgotten the task description.

Agent:

Three participants mentioned that it was the most difficult task to find video gallery which was Task 4 because they could not realize what the videos were. Other two participants, who showed Task 4 as the most difficult task, stated that there was a deficiency in navigator cues, and they did not want to get assistance from agents because they were responding slowly. Agent group participant 6 described that Task

4 was the most difficult task because there were too many things to memorize and maps would be beneficial although agents are effective.

4.4.4 Question 4: Did you realize that in order to complete a task, there exist more than one alternative?

Control:

All participants responded as “Yes” to this question. Control group participant 1 explained that there was a circular structure in the environment. Control group participant 6 described that because he was familiar with Multiplayer Online Games, he thought that there had to be a short-cut. As a result, he walked through off-road.

Map:

All participants responded as “Yes” to this question. Map group participant 4 stated that she tried to find out the shortest route.

Sign:

Five participants responded as “Yes” to this question while two participants as “No”. Sign group participant 5 who responded as “No”, declared that she would find out a short way to complete tasks if she would spend time in the environment.

Voice:

All participants responded as “Yes” to this question. Voice group participant 2 stated that even she did not use an alternative, she knew that it would be a short cut when she would use off-road. Voice group participant 3 explained that she listened to kiosks once and memorized them. She also pointed out that if she would look at standard signboards, it would take more time to complete tasks.

Agent:

Five participants responded as “Yes” to this question while one participants as “No”. Agent group participant 4 who responded as “No” additionally reported that because she was receiving destination description from agents, she focused on agents and did not realize alternative options.

4.4.5 Question 5: Were the options presented were sufficient and clear in order to complete tasks?

Control:

Four participants responded as solely “Yes” to this question. Control group participant 1 considered options as not sufficient and explained that he required teleporting not only between floors but also between buildings. Control group participant 2 stated that the options were excessive and confusing. He added that playing video games would be beneficial in completing tasks. Control group participant 4 considered options as excessive but clear, while control group participant 7 as not clear due to excess trees which restrict eyesight of the avatar.

Map:

Six participants responded as solely “Yes” to this question. Map group participant 3 required more options. Though considering options as sufficient, map group participant 6 complained about the existence of trees in addition to advice regarding the simultaneous usage of maps and signboards. Map group participant 7 considered options as confusing and added that she discovered that avatar could walk through off-road lately.

Sign:

Six participants responded as solely “Yes” to this question whereas one participant as “No”.

Voice:

Five participants responded as solely “Yes” to this question. Voice group participant 1 explained about the requirement of maps because voice and standard signboard were not insufficient.

Agent:

Four participants responded as solely “Yes” to this question. Agent group participant 3 stated that although the options were clear, more options would be better. Agent group participant 5 considered options as sufficient and clear, yet, he searched for signboards in the environment.

4.5 Summary of Results

In this study both quantitative and qualitative data analysis methods were utilized. General results of quantitative data analysis can be seen in Table 4.74. In this table average values of task completion time, task completion length, accuracy, navigation cue gaze duration and mental workload for all tasks. Better results were highlighted in yellow color and worse results were highlighted in red color.

In terms of usability, with respect to user performance and satisfaction signboard is more usable than other treatments.

To investigate whether is there significant difference between treatment groups in terms of task completion time, task completion length, accuracy, navigation cue gaze duration and mental workload one-way ANOVA and one-way repeated measures ANOVA analysis were conducted. General results were as follows:

Satisfaction: there was no significant difference among treatment groups.

Accuracy: there was a significant difference between control group and agent group.

Task completion time: there was a significant difference between map group and all other groups.

Task completion length: there was a significant difference between control group and signboard, agent groups also map group and signboard, agent groups.

Navigation cue gaze duration: there was a significant difference between signboard group and map group.

Workload on left hemisphere: there was a significant difference between control group and all other groups and also map group and voice group.

Table 4.74 Summary of results

	Map group						Signboard group						Voice group						Agent group						Control group																					
	Avg. TT	Avg. TL	A	WL	GD	St.	Avg. TT	Avg. TL	A	WL	GD	St.	Avg. TT	Avg. TL	A	WL	GD	St.	Avg. TT	Avg. TL	A	WL	GD	St.	Avg. TT	Avg. TL	A	WL	GD	St.																
Task 1	226	40	67%	1,396807	84	55	148	28	100%	1,482140	32	309	61	100%	0,139829	55	134	16	100%	2,077133	33	150	41	25%	-0,705724	N/A	184	55	38%	0,841638	N/A	202	55	100%	-1,141589	N/A	205	55	38%	0,841638	N/A	202	55	100%	-1,141589	N/A
Task 2	151	29	78%	1,658673	21	6	65	16	71%	0,904423	12	70	16	100%	0,373481	6	98	19	100%	2,389019	14	184	51	38%	0,841638	N/A	184	51	38%	0,841638	N/A	184	51	38%	0,841638	N/A	184	51	38%	0,841638	N/A	184	51	38%	0,841638	N/A
Task 3	188	38	89%	1,921413	32	5	54	12	86%	1,061248	12	46	11	100%	0,090114	5	82	11	100%	2,535380	7	184	51	38%	0,841638	N/A	184	51	38%	0,841638	N/A	184	51	38%	0,841638	N/A	184	51	38%	0,841638	N/A	184	51	38%	0,841638	N/A
Task 4	343	67	89%	1,592353	86	19	163	37	100%	1,097972	19	207	50	100%	0,130329	15	273	56	100%	2,806284	42	202	55	100%	-1,141589	N/A	202	55	100%	-1,141589	N/A	202	55	100%	-1,141589	N/A	202	55	100%	-1,141589	N/A	202	55	100%	-1,141589	N/A
Task 5	44	11	100%	1,504074	5	2	46	11	100%	0,889711	2	47	11	83%	0,319905	N/A	44	11	100%	3,174595	0	45	13	100%	-1,436326	N/A	45	13	100%	-1,436326	N/A	45	13	100%	-1,436326	N/A	45	13	100%	-1,436326	N/A	45	13	100%	-1,436326	N/A
Task 6	101	23	100%	1,926993	32	8	67	21	100%	0,389518	8	83	24	100%	0,162817	6	107	24	100%	2,835118	18	76	24	100%	-1,290142	N/A	76	24	100%	-1,290142	N/A	76	24	100%	-1,290142	N/A	76	24	100%	-1,290142	N/A	76	24	100%	-1,290142	N/A
Task 7	169	32	100%	2,430688	54	17	109	23	100%	0,741012	17	175	45	83%	0,350183	15	167	34	100%	2,823165	25	126	39	100%	-0,991841	N/A	126	39	100%	-0,991841	N/A	126	39	100%	-0,991841	N/A	126	39	100%	-0,991841	N/A	126	39	100%	-0,991841	N/A
Task 8	292	62	100%	2,943371	29	10	181	52	100%	1,742716	10	137	42	100%	0,761748	8	142	43	100%	3,574790	14	144	40	88%	-0,722358	N/A	144	40	88%	-0,722358	N/A	144	40	88%	-0,722358	N/A	144	40	88%	-0,722358	N/A	144	40	88%	-0,722358	N/A
Task 9	303	56	100%	1,714025	21	11	105	35	100%	1,291229	10	142	34	100%	1,028121	11	140	34	100%	3,873898	4	135	39	100%	-0,817742	N/A	135	39	100%	-0,817742	N/A	135	39	100%	-0,817742	N/A	135	39	100%	-0,817742	N/A	135	39	100%	-0,817742	N/A

CHAPTER5

DISCUSSION & CONCLUSION

In this study, four different types of way finding cues on usability of virtual worlds in terms of user satisfaction, user performance and mental workload were evaluated by seven means of data. Throughout this chapter results of the analysis conducted in the previous chapter discussed in detail.

5.1 User Satisfaction

The first set of data is based on SUS questionnaire aiming evaluate users how satisfied with the environment. The calculation of SUS score was explained in Chapter 3.3 in detail. Although the lowest US mean score was control group's with 55.31 and highest US mean score was signboard group's with 74.64, according to conducted one-way ANOVA there was not significantly mean difference between treatment groups with respect to US.

In spite of this result, control group's participants were the most dissatisfied with the environment according to mean US scores. Moreover, during the interview two of the participants stated that they were dissatisfied with the environment due to mostly absence of way finding cues in the campus. According to US score there is a tendency to increase among the sample group the ones used the environment with way finding affordance. Moreover, US mean score has a tendency to decrease while participants spent more time in the environment. For instance, signboard treatment group has the highest US mean score , whereas TTCL mean score was lowest between treatment groups.

Moreover, there could be a connection between presence of way finding affordance and US. Treatment group's mean US and TTCT scores shows that even though map treatment group's mean TTCT score was the highest among the groups, their US score was higher than control group's mean US score. It can be concluded that providing way finding affordances in virtual worlds could increase users' satisfaction.

When people introduce a new environment, they have a tendency to construct the environment in their minds in other words they try to construct cognitive map of the environment During construction of a cognitive map of the environment completing tasks takes much time and effort. This duration could be the tasks beginning of the experiment. According to results, 25 % of the participants did not complete the task success fly and this rate is 27% for second task. However, the participant spent more time in the environment accuracy rate is increasing. This result an increase of participants' satisfaction with the environment.

Chittaro et al. (2004), however, highlight that maps require much effort to interpret because the users have to construct egocentric perspective from exocentric perspective. The results of this study confirm that conclusion. The participants in the map group treatment, spent more time and travel around more in order to interpret the map find their location and decide which rout to take to complete the task. This process may reduce their satisfaction with the environment. On the other hand, agent group's participants had directions for their destinations therefore they did not have to convert any exocentric knowledge into egocentric knowledge and not worry about their location or feel of being lost. With the help of directions they were able to complete the tasks without losing time and travelling around.

5.2 Accuracy

Total task completion accuracy (TTCA) is the percentage of how many of nine tasks were completed successfully by the participants. Control group had the lowest mean TTCA score within all groups.

Except for control group, all group's participants mean TTCA score over 85%. In fact, participants in agent group completed each task successfully. Since there was no time limitation to complete a task every user tried to accomplish without concerning how much time they spent. There were just two participants who thought they could not complete the task and wanted to end pass on to next task. Therefore, there was a ceiling effect in distribution of TTCA dependent variable.

To investigate if there is a significant mean difference between treatment groups in terms of mean TTCA score one-way ANOVA was conducted. According to the results, there was a significant mean difference between control group and agent group. It is possible to explain the reason of the significant mean difference among groups in terms of TTCA is giving participants directions to their destination directly by simulated agents. Therefore, the participants in agent group was able to find their destinations without being lost. Another positive effects of giving directions by simulated agents could be lower TTCL mean score by not too much travelling around to find destination According to observations during the experiment and user interviews it is possible to state that both lower TTCL and TTCT mean scores related with higher US mean scores.

During construction of a cognitive map of the environment completing tasks takes much time and effort. This duration could be the tasks beginning of the experiment. According to results, 25 % of the participants did not complete the task successfully and this rate is 27% for second task. However, the participant spent more time in the environment accuracy rate is increasing.

5.3 Time

One of the user performance criteria is task completion time. Task completion time criteria used as both total task completion time (TTCT) and task completion time (TCT). There nine tasks in the environment. TTCT was calculated by adding up each task's completion time in terms of seconds. TCT is duration between participants' starting the task and completion in terms of seconds. According to the results signboard group's mean TTCT score was the lowest among the groups on the other

hand, map group's mean TTCT score was the highest. In order to investigate the effect of total task completion time (TTCT) among treatment groups one-way ANOVA analysis was conducted.

With respect to analysis results map group's mean TTCT score was significantly different than other four groups. In fact, map group's mean TTCT score was higher than all groups except for, control group. This result indicates that map group participants could not interpret the given way finding affordance in a short time, and eventually they spent more time during the experiment. According to Chittaro et al. (2004) maps require much effort to interpret because the users have to construct egocentric perspective from exocentric perspective. The results of this study confirms that conclusion. The participants in the map group treatment, spent more time and travel around more in order to interpret the map find their location and decide which route to take to complete the task. Moreover, the reason of why control group's mean TTCT score is higher than map group's is absence of way finding affordances in control group.

The experiment consists of nine different task which means there are nine different task completion time. Map group may differ from others due to one of these tasks' completion time significantly different from other task and there could be an interaction between treatments. To investigate this issue one-way repeated measures ANOVA was conducted.

The order of the tasks is given in specific order not randomly. METU virtual campus can be divided in three areas group working area, media center and faculties and departments. First three tasks are in group working area, following two tasks are in media center and remaining four tasks in faculties and departments area. There are two goals of this specific order. The first one is that comparability of quantitative data of the participants such as task completion time and task completion length. For instance, one user completes a task such as finding social area as first task then amphitheater as second. Another participant completes a task such as finding video gallery as a first task then finding amphitheater as second. The completion time and length for finding amphitheater are too different for these two participants even

though they go directly to the destination Therefore, it may mislead the results. The second reason of not randomly given tasks is to prevent users from repeating the same routes. According to literature repeating routes in an environment leads user to memorize the routes and eventually cognitive map of the environment develops in user's mind.

According to results, task completion time of number four task differs from task number 3, 5, 6 and 7. In fact, the time to complete task number four was higher . The reason of this task four's destination located in media center in a close environment. Therefore most of the participants traveled around more to find the destination. Another reason of why TCT-4 was higher than others is 73% of the participants successfully completed task number 3 which located in the course area the distance between task number four and task number three was too far from each other. With respect to user's interview results 28% participants reported that task number four was the most difficult task to complete.

Moreover, the time needed to complete task number 5 was significantly lower than task -1, 4, 6, 7, 8, and 9. The reason of this is the destination of task number five and task number four very close to each other they both located in media center. And also, participants while looking for task four destination most of them saw the task-number five and remembered during task five. Interview results shows that according to 11% of the participant task number five was the easiest task to complete for the previous reasons.

With respect to the results of the analysis the mean score of TCT-6 was significantly less from TCT-7, 8 and 9. The reason of this result is that convention center was located almost in the middle of the campus where the participants entered the environment. While participants were completing other tasks they noticed and remembered the location of convention center. Thus, the time needed participants to complete task number six was less. In fact, 11% participants reported that the easiest task to complete was task six and they reported as follows it was clearly visible and I passed through that target earlier.

Another important result of this analysis is there was no interaction effect between TCT and treatment groups which indicates that the difference between treatment groups does not come from any of the single task.

5.4 Length

One of the user performance criteria is task completion length. Task completion length criteria used as both total task completion length (TTCL) and task completion length (TCL). There nine tasks in the environment. TTCL was calculated by adding up each task's completion length in terms of meters. TCL is the length between participants' starting and completing of the task in terms of meters. According to the results signboard group's mean TTCL score was the lowest among the groups on the other hand, control group's mean TTCT score was the highest. In order to investigate the effect of total task completion length (TTCT) among treatment groups one-way ANOVA analysis was conducted.

According to the result of the analysis there is a significant mean difference between control group and signboard group, control group and agent group. And also, map group and signboard group, map group and agent group. in terms of TTCL. Control group's mean TTCL score was higher than signboard and agent groups. This result indicates that map group participants could not interpret the given map properly. It was observed that during the experiment map group's participants tried to find out their locations by checking at least two maps .If they find out where they are in the environment then they drew a rout to reach the destination. This process they travel around more than other groups. According to Chittaro et al. (2004) maps require much effort to interpret because the users have to construct egocentric perspective from exocentric perspective. The results of this study confirms that conclusion. The participants in the map group treatment, travel around more in order to interpret the map find their location and decide which route to take to complete the task. Of course control group's participants' travel around more than any of the group because of absence of any way finding affordance.

The experiment consists of nine different tasks which means there are nine different task completion lengths. Difference among the groups may result from one of these tasks' completion length significantly different from other task and there could be an interaction between treatments. To investigate this issue one-way repeated measures ANOVA was conducted.

According to results, task completion length of number four task differs from task number 3, 5, 6, 7 and 9. In fact, the length of the way the participants to complete task number four was higher. The reason of this task four's destination located in media center in a close environment. Therefore most of the participants traveled around more to find the destination. Another reason of why TCL-4 was higher than others is 73% of the participants successfully completed task number 3 which located in the course area the distance between task number four and task number three was too far from each other. With respect to user's interview results 28% participants reported that task number four was the most difficult task to complete.

Moreover, the length of the way the needed to complete task number 5 was significantly lower than task -5, 6, 7, 8, and 9. The reason of this is the destination of task number five and task number four very close to each other they both located in media center. And also, participants while looking for task four destination most of them saw the task-number five and remembered during task five. Interview results shows that according to 11% of the participant task number five was the easiest task to complete for the previous reasons.

With respect to the results of the analysis the mean score of TCL-6 was significantly less from TCL-7, 8 and 9. The reason of this result is that convention center was located almost in the middle of the campus where the participants entered the environment. While participants were completing other tasks they noticed and remembered the location of convention center. Thus, the length of the way the participants needed to complete task number six was less. In fact, 11% participants reported that the easiest task to complete was task six and they reported as follows it was clearly visible and I passed through that target earlier.

It was obvious that time and length results are very similar. However, at this point apart from time results task number eight shows significant mean difference in terms of task completion length from task-3 and 9. The reason for the difference was reported by 11% of the participants as the entrance was not seen due to trees in the environment. Therefore, participants traveled around more to find the destination.

Another important result of this analysis is there was no interaction effect between TCL and treatment groups which indicates that the difference between treatment groups does not come from any of the single task.

5.5 Standard Signboard Gaze Duration

One of the user performance indicators is total standard signboard gaze duration. Standard gaze duration is the duration of how long a participant looked at standard signboard while s/he completing the task. Standard signboard gaze duration used as both total value of nine tasks (TSSGD) and individually (SSGD) for each task. According to the results, map groups mean TSSGD score was the lowest and voice group's was the highest between the groups. To investigate whether there is a significant difference between treatment groups one-way ANOVA was conducted.

According to analysis there was no significant mean difference between treatment groups in terms of SSGD. Even though, statistically there was no significant difference among groups, it was observed that, the participants in the map group were tend to use less standard signboard. Because, they tried to memorize their destination's location and decide which route they take to reach that destination. Therefore, they look at standard signboard less with respect to other groups.

Moreover, according to mean SSGD score of voice group was higher than other treatment groups. The reason of why voice group looked standard signboard is that due to being audio the presented way finding affordances. Duration of presented audio cues were between six seconds to 25 seconds. While users were listening those audio cues they had a chance to look around and confirm what facilities or areas located behind the voice kiosks.

To investigate if there is a significant mean difference among nine tasks one-way repeated measures ANOVA was conducted. According to the results, SSGD-5 was the shortest duration since there was just one standard signboard in media center. As it was stated in previous sections, during task-4 most of the participants noticed the location of task-5. Therefore, the difference may result from these actions of the participants. Moreover, SSGD-6 has the same explanation as in previous sections. Being located center of the campus and the participants entering the environment very close to this location, and also while users completing other tasks seeing and memorizing its location could be the reason of why mean SSGD-6 score was lower than others.

Apart from the previous sections, SSGD-3 has a significant difference. There could be simple explanation for that. The route between task2- and task-3 was very short and there was just one standard signboard on the way. Moreover, mean SSGD-1 score was significantly higher than SSGD-5 and SSGD-6. Being first task in the environment users may have a tendency to paying too much attention to surroundings could be the reason of why SSGD-1 was higher than others.

Another important result of this analysis is there was no interaction effect between SSGD and treatment groups which indicates that the difference between treatment groups does not come from any of the single task.

5.6 Navigation Cues Gaze Duration

One of the user performance indicators is total navigation cues gaze duration. Navigation cues gaze duration is the duration of how long a participant looked at way finding affordances in this study map, signboard, voice kiosk and agent while s/he completing the task. Navigation cues gaze duration used as both total value of nine tasks (TNCGD) and individually (NCGD) for each task. According to the results, signboard group's mean TNCGD score was the lowest and voice group's was the highest between the groups. To investigate whether there is a significant difference between treatment groups one-way ANOVA was conducted.

According to results there was a significant mean difference between map group and signboard group in terms of TNCGD. The participants' in map group looked at their way finding affordance 243.356 seconds more than signboard group's. According to Chittaro and Burigat 2004 maps as way finding affordances require the user to continuously switch between egocentric and exocentric views as a result; The results of this study confirms that conclusion.

Another reason of why map group mean TNGCD score was higher than other groups could be the design of the given affordance. The given map could be described as a bird-eye view of the environment and with numbers on areas and buildings on it and a red point representing current location on the map was on the right side and names of numbered locations was left side of the map. Since there were 37 departments, five faculties and other buildings, the provided map was too large to see at one glance. Therefore, the users needed to enlarge the map to see and read the information. It was observed that users tried to first their location on the right side than move to the left side to learn where they were. During these come and go process between right and left side of the map participants tend to forget what they learnt before. In order to remember they repeats the same process few time. Eventually they increase TNCGD score also lost time and satisfaction. In fact, it was observed that during the experiment 78% map group's participants had trouble with interpreting map.

According the Choi (2011) there two main types of giving map as a way finding affordance. One is fixed into the environment and the other is detached from the environment. Fixed map is a part of the environment, users could not see the map at all the time. If the user wants to benefit from map s/he has to go to the map's location. However, detached maps are not located in the environment they are located main window's one of the corner so, they are visible at all time. According to Choi's (2011) study, the participants' performances used detached maps higher than the fixed one's. In our case, fixed maps were used. From mean TNCGD score of signboard group it is possible to say that lower TNCGD score means better user understanding provided way finding affordance.

To investigate if there is a significant mean difference among nine tasks one-way repeated measures ANOVA was conducted. According to the results, NCGD-4 was significantly higher than NCGD-3 and NCGD-5. The reason of why NCGD-4 was high is the distance between task-3 and task-4 longer with respect to other tasks. Therefore, users' mean NCGD-4 score was high. NCGD-5 was the shortest duration since there was few way finding affordances in media center. In fact, for map treatment group there were two maps in media center one was at the entrance and the other was located between galleries and cafeteria entrance; for signboard treatment group there were two signboards; one voice kiosk at entrance for voice treatment group. And one agent at the entrance for agent treatment group. As it was stated in previous sections, during task-4 most of the participants noticed the location of task-5. Therefore, the difference may result from these actions of the participants. Moreover, NCGD-6 has the same explanation as in previous sections. Being located center of the campus and the participants entering the environment very close to this location, and also while users completing other tasks seeing and memorizing its location could be the reason of why mean NCGD-6 score was lower than NCGD-7.

Another important result of this analysis is there was no interaction effect between NCGD and treatment groups which indicates that the difference between treatment groups does not come from any of the single task.

5.7 Workload

Another user performance indicator is mental work load evaluated by fNIR device as oxygenation level. It was obvious that, in all oxygenation graph control group's mean scores were negative. The reason of negative mean scores of control group may be the participants bored or disengaged with the experiment.

To investigate whether there is a significant mean difference between treatment groups in terms of mental workload one-way ANOVA was conducted for left and right hemispheres voxel-6 and voxel-16. According to the results of the analysis there was a significantly mean difference between control group and remaining

groups also map group and voice group in terms of left hemisphere's mental workload.

Disengagement of the tasks and boredom could be possible explanation of control group's difference from others. In fact, with respect to other results of control group it could be expected. Because user satisfaction was the lowest, total task completion time was higher than remaining group's except for map group and also, total task completion length score was highest. Moreover, with respect to interview results most of the control group's participants reported that they were uncomfortable with the environment due to absence of way finding affordances.

The mean LHA score was significantly lower than agent group's mean score. Except for voice kiosk, remaining way finding affordances were visually demanding. According to Elvins (1997), the majority of information required for forming the cognitive map is visual, similarly most navigation aids in the virtual environment are visually demanding. Presenting navigation cue by audio channel may reduce the mental workload coming from visual channels. Moreover, Chittaro et al. (2004) maps require much effort to interpret because the users have to construct egocentric perspective from exocentric perspective. The results of this study confirms that conclusion. The participants in the map group treatment, travel around more in order to interpret the map find their location and decide which route to take to complete the task. These procedures also could increase the mental workload in left hemisphere.

According to mean RHA scores, there was a significant difference between control groups and remaining groups, also there was a significant mean difference signboard group and agent group. Moreover, voice group and agent group were significantly different from each other. The reason of control group's difference could be possible disengagement and boredom with the environment. However, the difference of agent group's mean During the experiment the participants needed to say which task they were in in order to get help from the agent. Agent group's mean RHA score difference could arise from this implementation. Moreover, it was observed that mental workload in left hemisphere was highest in map group and mental workload in right hemisphere was the highest in agent groups. However, mental workload in

both hemispheres was lower in signboard and voice groups with respect to map and agent groups.

One-way repeated measure ANOVA analyses were conducted whether there was a significant mean difference among tasks in terms of workload. This procedure was repeated for voxel-6 and voxel-16. With respect to the result, task-8 higher from others in terms of workload. This indicates that users compelled mentally during task-8.

5.8 Conclusion

When people introduce a new environment, they have a tendency to construct the environment in their minds in other words they try to construct cognitive map of the environment. During construction of a cognitive map of the environment completing tasks takes much time and effort. This duration could be the tasks beginning of the experiment. According to results, 25 % of the participants did not complete the task successfully and this rate is 27% for second task. However, the participant spent more time in the environment accuracy rate is increasing. This result an increase of participant's satisfaction with the environment. Egocentric and exocentric views are two of the perspectives that are used in exploring virtual environments. These two view types can be combined during exploration. In egocentric view, the user is embedded in virtual environment and s/he interacts from inside the environment whereas s/he interacts from outside in exocentric view (Wickens and P. Baker, 1995).

This study revealed that using way finding affordance importance on user satisfaction, performance and mental workload. The groups using way finding affordance outperformed the control group. Moreover, a proper way finding affordance should provide higher user satisfaction, less task completion time, length and raise less mental workload. It may not be possible to achieve all these aspects. Therefore, to achieve these goal different types of way finding affordances could be utilized at the same environment. However, this study revealed that signboard way finding affordance provided highest user satisfaction and task completion accuracy, lowest task completion time and length and arises relatively less mental workload.

Design of the way finding affordance is a crucial issue. For instance, it was observed that map group's participants lost too much time and mental effort to interpret the map since there was too much information on the map. Moreover, agent simulation could not work properly because agents answered the questions late. Therefore users lost their time and satisfaction.

5.9 Recommendations For Virtual World Design

According to result of the study and observations made during the study following recommendations provided in virtual world design.

During the experiments most of the participants could not complete the tasks could not be seen directly and they reported that they could not finish the task because of not seeing the destinations directly. In fact, some of the participants reported that some of the tasks were hidid intentionally. On the other hand, the tasks located in open areas could achieve most of the participants. Moreover, they reported the reason of why they accomplish them is destinations could be seen from a distance. Therefore, Make sure all destinations are visible by user

Way finding affordance in a virtual world could be provided by mix of different types of affordances. Moreover, participants demand different types of affordances. For instance, map group participants demanded signboards as a second way finding affordance, voice kiosk group demanded map as a different affordance, and also agent group demanded signboards. Each type of affordance provides different information to the user. For instance, map provides external view of the environment, signboards interpreted faster and agents provide exact description of the destination. Using just one type of way finding affordance in a virtual world could decrease the usability of the virtual environment. Therefore, using combination of way finding affordances may provide better user experience.

In the study two of the participants felt dizziness and nausea because of travelling confined areas. Therefore, their experiments stopped immediately. Moreover, in confined areas such as inside of a classroom or a video gallery users could lose their

locations and motivation easily. Hence, using less or non-confined spaces may increase user performance and satisfaction.

Different virtual world platforms provide their own features. In Second life, teleporting is one of the most important feature. An avatar could teleport itself from one location to another location. teleporting costs less time than getting the same destination by flying and walking. In this study, some of the tasks located in a room of a building , different buildings and areas. Using teleport tool between floors of the same building, different buildings and areas instead of flying or walking may increase user performance and satisfaction. However, this time developing of the cognitive map of the environment in users mind takes much time than other way finding affordances'. Because, users could not see the environment while travelling.

Designing the way finding affordance has a crucial importance. The affordance provide brief, important information and should not require too much time to be interpreted. For instance, map provided in this study provides information about 37 departments, 5 faculties, and 2 different areas. The participants needed much time to interpret those information at once. On the other hand, the participants in signboard group were able to interpret the provided signs in a short time.

5.10 Future Studies

In furtherer studies the following topics could be investigated.

- Gender effects on way finding affordance.
There are many studies investigating gender difference using fMRI and eye tracking methodology. However, there are few research using both devices at the same time.
- Education level effects on way finding affordances.
During the study, it was observed that participants from different departments showed different performance. In further studies different education discipline effects could be investigated.
- Effects on playing video game frequency on way finding affordances

During the experiments it was observed that most of the participants claimed that if they had played video games more frequently, they would have shown better performance in the experiment. In further studies effects of playing video game frequency on user performance could be investigated.

- Combination of different way finding affordance effects could be investigated.

Each type of affordance provides different information to the user. For instance, map provides external view of the environment, signboards interpreted faster and agents provide exact description of the destination. Using just one type of way finding affordance in a virtual world could decrease the usability of the virtual environment. Therefore, using combination of way finding affordances may provide better user experience.

- Voice and agent way finding affordance could be developed and investigated. Due to the Second Life environment's technical properties sound files longer than 10 seconds could not be played properly. Also, agents were simulated by real persons but their replications were as not fast as real agents. Therefore, these two conditions could be investigated thoroughly in future.
- Proper fNIR sensor pad and new version of Tobii studio software this study could be repeated.

The sensor pad of fNIR device produced with standardized dimensions. There were no specific sensor pads for male or female participants. Therefore, both female and male participants had to wear same sensor pad. The pad was little much bigger for female participants' forehead. Therefore, the sensors located upper side of the pad could not be placed right locations. In fact they contacted most of the female participants' hair. However, the sensors located upper side of the pad placed properly on most of the male participants' forehead. The reason of the difference was generally female forehead smaller than male ones.

Tobii Studio 2.2.4 was design to analyze 2D environments such as web pages. However, this experiment was conducted in a 3D environment. The

software has the ability of defining area of interest but this feature works properly in 2D settings.

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APPENDIX A

ETHICAL COMITTE APPROVAL


1956

Orta Doğu Teknik Üniversitesi
Middle East Technical University
Fen Bilimleri Enstitüsü
Graduate School of
Natural and Applied Sciences
06800 Ankara, Türkiye
Phone: +90 (312) 2102292
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Sayı: B.30.2.ODT.O.40.05.02/126/ *3567 - 15201* 22.12.2011

GÖNDERİLEN: Prof. Dr. Belgin Ayvaşık
Rektör Danışmanı

GÖNDEREN : Prof. Dr. Gürsevil Turan
Fen Bilimleri Enstitüsü
Müdür Yardımcısı *Gürsevil Turan*

KONU : Yavar Cansız hk.

Bilgisayar ve Öğretim Teknolojileri Eğitimi EABD yüksek lisans programı öğrencisi Yavar Cansız'ın 15 Aralık 2011 – 15 Mayıs 2012 tarihleri arasında "Sanal ortamlarda göz izleme aracı ve beyin aktivitesini görüntüleme amaçla spektroskopik ile kullanılabilirlik testi" başlıklı araştırmasına ilişkin hazırlanan anketi ODTÜ BİDB İBE Laboratuvarında uygulama yapmak için görevlendirilme başvurusu incelenmiş; ilgili danışman görüşüne dayanarak adı geçen öğrencinin isteği doğrultusunda görevlendirilmesine Etik Komite onayı koşulu ile uygun görülmüştür.

Gereği için bilgilerinize saygılarımla sunarım.

Ek: EYK kararı ve ekleri

Etik Komite Onayı
Uygundur
22.12.2011
Canan Özgen
Prof. Dr. Canan Özgen
Uygulamalı Etik Araştırma
Merkezi (UEAM) Başkanı
ODTÜ 06531 ANKARA

1260
27/12
23/12

ÖİDB
Bilgi için gereği:
riçesiyle
ca
27/12
Prof. Dr. Belgin AYVAŞIK
Rektör Danışmanı

O.D.T.Ü
FEN BİLİMLERİ ENSTİTÜSÜ
YÖNETİM KURULU KARARI

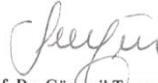
Tarih: 22.12.2011
Sayı: FBE: 2011/ 11

GÖREVLENDİRME VE İZİN

Bilgisayar ve Öğretim Teknolojileri Eğitimi EABD yüksek lisans programı öğrencisi Yaver Cansız'ın 15 Aralık 2011 – 15 Mayıs 2012 tarihleri arasında "Sanal ortamlarda göz izleme aracı ve beyin aktivitesini görüntüleme amaçla spektroskopi ile kullanılabilirlik testi " başlıklı araştırmasına ilişkin hazırlanan anketi ODTÜ BİDB İBE Laboratuvarında uygulama yapmak için görevlendirilme başvurusu incelenmiş; ilgili danışman görüşüne dayanarak adı geçen öğrencinin isteği doğrultusunda görevlendirilmesine oybirliği ile karar verilmiştir.



Prof. Dr. Canan Özgen
FBE Müdürü



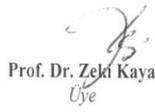
Prof. Dr. Gürsevil Türan
FBE Müd. Yard.



Doç. Dr. Nil Uzun
FBE Müd. Yard.



Prof. Dr. Haluk Sucuoğlu
Üye



Prof. Dr. Zeki Kaya
Üye



Y. Doç. Dr. Buğra Koku
Üye

APPENDIX B

CONSENT FORM



Gönüllü Katılım Formu

Bu çalışma, ODTÜ Bilgisayar Öğretim Teknolojileri Eğitimi (BÖTE) Bölümünde Öğretim Görevlisi Yrd. Doç. Dr. Saniye Tuba Bulu danışmanlığında ve İşletme Bölümü Öğretim Görevlisi Tunç Medeni yardımcı danışmanlığında Yüksek Lisans Öğrencisi Yaver Cansız tarafından yapılan yüksek lisans tezi kapsamında 3 boyutlu öğrenme ortamlarının göz izleme ve FNIR cihazları kullanılarak değerlendirilmesi amacıyla yürütülmektedir.

Çalışmanın amacı; 3 Boyutlu sanal ortamlarda; yer/yön gösteren işaretlerin, haritaların, yardımcı yazılımların kullanıcıların performanslarını, bilişsel yüklerini ve memnuniyetlerini nasıl etkilediğini belirlemektir.

Bu çalışma süresince kullanıcıların 3 boyutlu öğrenme ortamıyla olan etkileşimi göz izleme ve fNIR cihazı tarafından kaydedilecektir. Uygulama öncesi kullanıcıların yaş/cinsiyet/bölüm/sınıf bilgilerini edinmemizi sağlayacak bir anket verilmektedir. Yapılacak çalışma 25 öğrenciye uygulanacak ve bütün çalışmalar İnsan Bilgisayar Etkileşim Araştırma ve Uygulama Laboratuvarında gerçekleştirilecektir.

Bilgileriniz tamamıyla gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir, elde edilen bilgiler yüksek lisans tezi kapsamında ve bilimsel yayımlarda kullanılacaktır. Uygulama sırasında sorulardan ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz cevaplama işini yarıda bırakıp çıkmakta

serbestsiniz. Böyle bir durumda uygulamayı yürüten kişiye, uygulamayı ya da soruları tamamlamadığınızı söylemek yeterli olacaktır. Uygulama sonunda, bu çalışmayla ilgili sorularınız cevaplanacaktır. Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz.

Çalışma hakkında daha fazla bilgi almak için Bilgi İşlem Daire Başkanlığı Sistem Yöneticisi Yaver Cansız ile (Oda: Z10; Tel: 210 3308; E-posta: ycansiz@metu.edu.tr) iletişim kurabilirsiniz.

Bu çalışmaya tamamen gönüllü olarak katılıyorum ve istediğim zaman yarıda kesip çıkabileceğimi biliyorum. Verdiğim bilgilerin bilimsel amaçlı yayımlarda kullanılmasını kabul ediyorum. (Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

İsim Soyad

Tarih

İmza

__/ /

APPENDIX C

USER INFORMATION QUESTIONNAIRE



KATILIMCI BİLGİ ANKETİ

Bu çalışma Orta Doğu Teknik Üniversitesi (ODTÜ), Eğitim Fakültesi, Bilgisayar ve Öğretim Teknolojileri Eğitimi (BÖTE) yüksek lisans öğrencisi Yaver CANSIZ tarafından yürütülmektedir.

Bu anket genel olarak; eğitim durumunuz, İngilizce seviyeniz, internet kullanımınız, sanal dünyalar hakkındaki bilginiz ve bilgisayar oyunları hakkındaki tercihlerinizi öğrenmek amaçlı sorular içermektedir.

Cevaplarınız kesinlikle gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecek, bu formdaki bilgilerinizle eşleştirme yapılmayacaktır. Elde edilecek bilgiler bilimsel yayımlarda kullanılacaktır.

Ad-Soyad: _____

E-posta: _____

1. Cinsiyetiniz:
 Bay Bayan
2. Yaşınız: _____
3. Eğitim durumunuz nedir?
 İlkokul Üniversite - Lisans
 Ortaokul Üniversite - Yüksek Lisans
 Lise Üniversite - Doktora
4. Üniversite (Lisans/Yüksek Lisans/Doktora) öğrencisi iseniz Bölümünüz:

5. İngilizce seviyeniz nedir?
 Başlangıç
 Orta
 İyi
 Çok iyi
6. Günde kaç saat internet kullanıyorsunuz?
 2 saatten az 2-4 saat arası 4-6 saat arası
 6-8 saat arası 8 saatten fazla
7. Sanal dünyalara üyelik durumunuz nedir?
 Sanal dünyalar hakkında bilgim yok.
 Bilgim var fakat üye değilim.
 Sanal dünyaların birine veya birden fazlasına üyeyim.

8. Aşağıdaki sanal dünyalardan hangi veya hangilerine üyesiniz? (Sizin için uygun olan bir veya birden fazla ifadeyi işaretleyebilirsiniz)

- Second life There Active worlds
- Sims Diğer (Belirtiniz): _____

9. Bilgisayar ve video oyunları oynuyor musunuz?

- Daha önce bilgisayar oyunu oynamadım.
- Bilgisayar oyunu oynuyorum.

10. Haftada kaç saat bilgisayar oyunu oynuyorsunuz?

- 2 saaten az 2-4 saat arası 4-6 saat arası
- 6-8 saat arası 8 saaten fazla

Sorular bitmiştir. Çalışmamıza katıldığınız için teşekkürler.

APPENDIX D

USABILITY QUESTIONNAIRE



KATILIMCI MEMNUNİYET ANKETİ

Bu çalışma Orta Doğu Teknik Üniversitesi (ODTÜ), Eğitim Fakültesi, Bilgisayar ve Öğretim Teknolojileri Eğitimi (BÖTE) yüksek lisans öğrencisi Yaver CANSIZ tarafından yürütülmektedir.

Bu anket genel olarak Second Life sanal ortamındaki hazırlanan ODTÜ sanal kampüsünde yaptığınız aktivitelerden ne ölçüde memnun kalıp, kalmadığınızı öğrenmek amaçlı sorular içermektedir.

Cevaplarınız kesinlikle gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecek, bu formdaki bilgilerinizle eşleştirme yapılmayacaktır. Elde edilecek bilgiler bilimsel yayımlarda kullanılacaktır.

Ad-Soyad: _____

E-posta: _____

	Kesinlikle Katılmıyorum				Kesinlikle Katılıyorum
1. Bu ortamı sıklıkla kullanacağımı düşünüyorum.	1	2	3	4	5
2. Ortamı gereğinden fazla karmaşık buldum.	1	2	3	4	5
3. Ortamın kolay kullanıldığını düşünüyorum.	1	2	3	4	5
4. Ortamı kullanmak için teknik bir kişiden destek almam gerektiğini düşünüyorum.	1	2	3	4	5
5. Ortamın içerisindeki çeşitli fonksiyonları iyi entegre edilmiş buldum.	1	2	3	4	5
6. Ortam içerisinde çok fazla tutarsızlık olduğunu düşünüyorum.	1	2	3	4	5
7. Bir çok insanın bu ortamı hızlı bir şekilde kullanabileceğini düşünüyorum.	1	2	3	4	5
8. Ortamın kullanımını çok hantal ve yavaş buldum.	1	2	3	4	5
9. Ortamı kullanırken kendimden emindim.	1	2	3	4	5
10. Bu ortamla çalışmaya başlamadan önce bir çok şey öğrenmem gerekti.	1	2	3	4	5

Sorular bitmiştir. Çalışmamıza katıldığınız için teşekkürler.

APPENDIX E

OBSERVATION SHEETS



DENEY GÖZLEM FORMU

Ad-Soyad: _____

Vaka: _____

Görev 0: _____

Tamamladığı süre: _____

Görevi sırasında uyguladığı method: _____

Notlar: _____

Vaka: _____

Görev 1: _____

Tamamladığı süre: _____

Görevi sırasında uyguladığı method: _____

Notlar: _____

Vaka: _____

Görev 2: _____

Tamamladığı süre: _____

Görevi sırasında uyguladığı method: _____

Notlar: _____

Vaka: _____

Görev 3: _____

Tamamladığı süre: _____

Görevi sırasında uyguladığı method: _____

Notlar: _____

Vaka: _____

Görev 4: _____

Tamamladığı süre: _____

Görevi sırasında uyguladığı method: _____

Notlar: _____

Vaka: _____

Görev 5: _____

Tamamladığı süre: _____

Görevi sırasında uyguladığı method: _____

Notlar: _____

Vaka: _____

Görev 6: _____

Tamamladığı süre: _____

Görevi sırasında uyguladığı method: _____

Notlar: _____

Vaka: _____

Görev 7: _____

Tamamladığı süre: _____

Görevi sırasında uyguladığı method: _____

Notlar: _____

Vaka: _____

Görev 8: _____

Tamamladığı süre: _____

Görevi sırasında uyguladığı method: _____

Notlar: _____

Vaka: _____

Görev 9: _____

Tamamladığı süre: _____

Görevi sırasında uyguladığı method: _____

Notlar: _____

APPENDIX F

INTERVIEW QUESTIONS



MÜLAKAT SORUKARI

Ad-Soyad: _____

1. Görevleri yaparken kendinize bir method belirlediniz mi?

2. Hangi görev sizin için en kolaydı? Bu kolaylığın nedenleri sizce nedir?

3. Hangi görev sizin için en zordu? Bu zorluğun nedenleri sizce nedir? Bu görev nasıl daha kolay hale gelirdi?

- 4. Bir görevi tamamlamak için birden fazla seçenek olduğunu farkettiler mi?**

- 5. Görevleri tamamlamak için sunulan seçenekler yeterli ve anlaşılabilir miydi?**

APPENDIX G

PARTICIPANT INFORMATION FORM



KATILIM SONRASI BİLGİ FORMU

Bu çalışma daha önce de belirtildiği gibi ODTÜ Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü (BÖTE) öğretim üyesi Yrd.Doç.Dr. Saniye Tuğba BULU ve danışmanlık ettiği yüksek lisans öğrencisi Yaver CANSIZ tarafından yürütülmektedir.

Çalışmanın amacı; 3 Boyutlu sanal ortamlarda; yer/yön gösteren işaretlerin, haritaların, yardımcı yazılımların kullanıcıların performanslarını, bilişsel yüklerini ve memnuniyetlerini nasıl etkilediğini belirlemektir

Bu çalışmadan alınacak ilk verilerin Şubat 2012 sonunda elde edilmesi amaçlanmaktadır. Elde edilen bilgiler sadece bilimsel araştırma ve yazılarda kullanılacaktır. Çalışmanın sonuçlarını öğrenmek ya da bu araştırma hakkında daha fazla bilgi almak için aşağıdaki isimlere başvurabilirsiniz. Bu araştırmaya katıldığınız için tekrar çok teşekkür ederiz.

Yrd. Doç. Dr. Saniye Tuğba BULU (Tel: 0312 210 75 20; E-posta: stugba@metu.edu.tr)

YL. Öğrencisi Yaver CANSIZ (Tel: 0312 210 33 08; E-posta: ycansiz@metu.edu.tr)

APPENDIX H

AGENTS' DIRECTIONS

AGENT-1:

Görev-1 : Grup çalışma alanında sosyal alanı bulup bir sandalyeye oturma.

Verilecek cevap: (Grup çalışma alanının olduğu Yön gösterilerek (birkaç adım o tarafa yürünebilir.))

Bu yönden ilerlerseniz grup çalışma alanına ulaşırsınız. Grup çalışma alanı levhasından sonra düz ilerleyin. Yol ayrımından düz ilerleyin sosyal alan levhasını göreceksiniz.

Görev-2: Grup çalışma alanında amfi-tiyatroyu bulup bir mindere oturma.

Verilecek cevap: (Grup çalışma alanının olduğu Yön gösterilerek (birkaç adım o tarafa yürünebilir.))

Bu yönden ilerlerseniz grup çalışma alanına ulaşırsınız. Grup çalışma alanı levhasından sonra düz ilerleyin. Grup toplantı alanını geçtikten sonra sağ tarafta denizin üzerindeki amfi-tiyatroyu göreceksiniz.

Görev-3: Grup çalışma alanında bir sanal sınıfta bir sandalyeye oturma.

Verilecek cevap: (Grup çalışma alanının olduğu Yön gösterilerek (birkaç adım o tarafa yürünebilir.))

Bu yönden ilerlerseniz grup çalışma alanına ulaşırsınız. Grup çalışma alanı levhasının karşısındaki yolu takip edin. Merdivenlerden inin ve ilerleyin. Karşınıza sanal sınıf çıkacaktır.

Görev-4: Medya merkezindeki video galerisini bulup bir videoyu başlatıp durdurma.

Verilecek cevap: (Medya merkezinin olduğu alan gösterilerek(birkaç adım o tarafa yürünebilir.))

Bu yönde ilerlerseniz Medya merkezine ulaşırsınız. Medya merkezine girdikten sonra düz ilerlerseniz fotoğraf galerisinin arkasında video galerisine ulaşırsınız.

Görev-5: Medya merkezinde kafeteryayı bulup bir sandalye veya koltuğa oturma.

Verilecek cevap: (Medya merkezinin olduğu alan gösterilerek(birkaç adım o tarafa yürünebilir.))

Bu yönde ilerlerseniz Medya merkezine ulaşırsınız. Medya merkezine girdikten sonra düz ilerlerseniz sırasıyla fotoğraf galerisine, video galerisine ardından kafeterya ve diskoya ulaşırsınız.

Görev-6: Kongre merkezini bulup bir sandalyeye oturma.

Verilecek cevap: (Kongre merkezinin olduğu alan gösterilerek(Birkaç adım o tarafa yürüyerek))

Bu yönde ilerlerseniz sağ tarafınızda kongre merkezine ulaşırsınız.

Görev-7: Mimarlık fakültesinde endüstri ürünleri tasarımı bölümünün bulunduğu kata çıkma.

Verilecek cevap: (Mimarlık fakültesinin olduğu taraf gösterilerek(Birkaç adım o tarafa yürüyerek)).

Bu yönde ilerleyin kongre merkezini geçtikten sonra bulunduğunuz yolu takip edin. Yolun sağında Mimarlık fakültesi levhasını göreceksiniz. Endüstri ürünleri tasarımı bölümü Mimarlık fakültesi b-blok 1. Kattadır.

Görev-8: Fen edebiyat fakültesi amfisini bulup bir sandeleyeye oturma.

Verilecek cevap: (İktisadi ve idari bilimler fakültesinin olduğu yön gösterilerek (Birkaç adım o tarafa yürünerek)).

Bu yönde ilerleyin kongre merkezini geçtikten sonra bulunduğunuz yolu takip edin. Yolun solunda sırasıyla İktisadi ve İdari bilimler fakültesinin sonra Fen Edebiyat fakültesinin levhalarını göreceksiniz. Fen edebiyat fakültesi levhasının arkasından ilerlerseniz amfiyi göreceksiniz.

Görev-9: Eğitim fakültesinde eğitim bilimlerinin bulunduğu kata çıkma.

Verilecek cevap: (Mimarlık fakültesinin olduğu yön gösterilerek (Birkaç adım o tarafa yürüyerek)).

Bu yönde ilerleyin kongre merkezini geçtikten sonra bulunduğunuz yolu takip edin. Yolun sağında Mimarlık fakültesinin sonra Eğitim Fakültesinin levhasını göreceksiniz. Eğitim bilimleri bölümü Eğitim fakültesi b-blok 3. Kattadır.

AGENT-2:

Görev-1: Grup çalışma alanında sosyal alanı bulup bir sandalyeye oturma.

Verilecek cevap: (Sosyal alanın olduğu yön gösterilerek (Birkaç adım o tarafa yürünerek)).

Bu yönde ilerleyin, yol ayrımında soldaki yoldan ilerleyin. Sağ tarafınızda sosyal alan levhasını göreceksiniz.

Görev-2: Grup çalışma alanında amfi-tiyatroyu bulup bir mindere oturma.

Verilecek cevap: (Amfinin olduğu yön gösterilerek (Birkaç adım o tarafa yürünerek)). Bu yönde ilerleyin, yol ayrımında soldaki yoldan ilerleyin. Grup toplantı alanını geçtikten sonra sağ tarafta denizin üzerindeki amfi-tiyatroyu göreceksiniz.

Görev-3: Grup çalışma alanında bir sanal sınıfta bir sandalyeye oturma.

Verilecek cevap: (sol tarafta ki yoldan Sanal sınıfların olduğu yön gösterilerek (Birkaç adım o tarafa yürünerek)).

Bu yolu takip ederek merdivenlerden inin ve ilerleyin. Karşınıza sanal sınıf çıkacaktır.

Görev-4: Medya merkezindeki video galerisini bulup bir videoyu başlatıp durdurma.

Verilecek cevap: (Merkez nokta gösterilerek (Birkaç adım o noktaya yürünerek)).

Bu yönden ilerleyin. İlk sağdan dönüp ilerlediğinizde medya merkezine ulaşırsınız. Medya merkezine girdikten sonra düz ilerlerseniz fotoğraf galerisinin arkasında video galerisine ulaşırsınız.

Görev-5: Medya merkezinde kafeteryayı bulup bir sandalye veya koltuğa oturma.

Verilecek cevap: (Merkez nokta gösterilerek (Birkaç adım o noktaya yürünerek)).

Bu yönden ilerleyin. İlk sağdan dönüp ilerlediğinizde medya merkezine ulaşırsınız. Medya merkezine girdikten sonra düz ilerlerseniz sırasıyla fotoğraf galerisine, video galerisine ardından kafeterya ve diskoya ulaşırsınız.

Görev-6: Kongre merkezini bulup bir sandalyeye oturma.

Verilecek cevap: (Merkez nokta gösterilerek (Birkaç adım o noktaya yürünerek)).

Bu yönde hiç sağa sola sapmadan ilerleyin. Yolun sağında kongre merkezine ulaşırsınız.

Görev-7: Mimarlık fakültesinde endüstri ürünleri tasarımı bölümünün bulunduğu kata çıkma.

Verilecek cevap: (Merkez nokta gösterilerek (Birkaç adım o noktaya yürünerek)).

Bu yönde hiç sağa sola sapmadan ilerleyin. Yolun solundaki kongre merkezini geçtikten sonra bulunduğunuz yolu takip edin. Yolun sağında Mimarlık fakültesi levhasını göreceksiniz. Endüstri ürünleri tasarımı bölümü Mimarlık fakültesi b-blok 1. Kattadır.

Görev-8: Fen edebiyat fakültesi amfisini bulup bir sandeleyeye oturma.

Verilecek cevap: (Merkez nokta gösterilerek (Birkaç adım o noktaya yürünerek)).

Bu yönde ilerleyin. İlk soldan dönüp ilerlediğinizde kongre merkezini geçtikten sonra bulunduğunuz yolu takip edin. Yolun solunda sırasıyla İktisadi ve İdari bilimler fakültesinin sonra Fen Edebiyat fakültesinin levhalarını göreceksiniz. Fen edebiyat fakültesi levhasının arkasından ilerlerseniz amfiyi göreceksinizGörev-9: Eğitim fakültesinde eğitim bilimlerinin bulunduğu kata çıkma.

Görev-9: Eğitim fakültesinde eğitim bilimlerinin bulunduğu kata çıkma.

Verilecek cevap: (Merkez nokta gösterilerek (Birkaç adım o noktaya yürünerek)).

Bu yönde hiç sağa sola sapmadan ilerleyin. Yolun solundaki kongre merkezini geçtikten sonra bulunduğunuz yolu takip edin. Yolun sağında Mimarlık fakültesinin sonra Eğitim Fakültesinin levhasını göreceksiniz. Eğitim bilimleri bölümü Eğitim fakültesi b-blok 3. Kattadır.

AGENT-3:

Görev-1 : Grup çalışma alanında sosyal alanı bulup bir sandalyeye oturma.

Verilecek cevap: (Sosyal alan gösterilerek(Birkaç adım o yöne doğru yürüyerek)).

Bu yönde ilerleyin. Karşınıza çıkacak yol ayırımından sağa dönün yolun sağında sosyal alan levhasını göreceksiniz.

Görev-2: Grup çalışma alanında amfi-tiyatroyu bulup bir mindere oturma.

Verilecek cevap: (Amfi-tiyatro gösterilerek)

Şuanda amfi-tiyatro girişindesiniz.

Görev-3: Grup çalışma alanında bir sanal sınıfta bir sandalyeye oturma.

Verilecek cevap: (Sanal sınıfların bulunduğu yön gösterilerek(Birkaç adım o yöne doğru yürüyerek)).

Bu yönde ilerlerseniz yolun sağında sanal sınıf levhalarını göreceksiniz.

Görev-4: Medya merkezindeki video galerisini bulup bir videoyu başlatıp durdurma.

Verilecek cevap: (Medya merkezi gösterilerek(Birkaç adım o yöne doğru yürüyerek)).

Bu yönden ilerleyin. Sanal sınıfları geçin merdivenleri çıkın. İlk sağdan dönün ve ilerleyin sonra tekrar sağa dönüp düz devam ettiğinizde medya merkezine ulaşırsınız. Medya merkezine girdikten sonra düz ilerlerseniz fotoğraf galerisinin arkasında video galerisine ulaşırsınız.

Görev-5: Medya merkezinde kafeteryayı bulup bir sandalye veya koltuğa oturma.

Verilecek cevap: (Medya merkezi gösterilerek(Birkaç adım o yöne doğru yürüyerek)).

Bu yönden ilerleyin. Sanal sınıfları geçin merdivenleri çıkın. İlk sağdan dönün ve ilerleyin sonra tekrar sağa dönüp düz devam ettiğinizde medya merkezine ulaşırsınız. Medya merkezine girdikten sonra düz ilerlerseniz sırasıyla fotoğraf galerisine, video galerisine ardından kafeterya ve diskoya ulaşırsınız.

Görev-6: Kongre merkezini bulup bir sandalyeye oturma.

Verilecek cevap: (Kongre merkezi gösterilerek(Bu yönde birkaç adım yürüyerek)).

Bu yönde hiç sağa ve sola sapmadan düz ilerleyin. Merkez noktayı geçin. Yolun solunda kongre merkezine ulaşırsınız.

Görev-7: Mimarlık fakültesinde endüstri ürünleri tasarımı bölümünün bulunduğu kata çıkma.

Verilecek cevap: (Merkez nokta gösterilerek (Bu yönde birkaç adım yürüyerek)).

Bu yönde hiç sağa ve sola sapmadan düz ilerleyin. Merkez noktayı geçin. Yolun solundaki kongre merkezini geçtikten sonra bulunduğunuz yolu takip edin. Yolun sağında Mimarlık fakültesi levhasını göreceksiniz. Endüstri ürünleri tasarımı bölümü Mimarlık fakültesi b-blok 1. Kattadır.

Görev-8: Fen edebiyat fakültesi amfisini bulup bir sandeleyeye oturma.

Verilecek cevap: (Merkez nokta gösterilerek (Bu yönde birkaç adım yürüyerek)).

Bu yönde hiç sağa ve sola sapmadan düz ilerleyin. Merkez noktada ilk soldan dönüp ilerlediğinizde kongre merkezini geçtikten sonra bulunduğunuz yolu takip edin. Yolun solunda sırasıyla İktisadi ve İdari bilimler fakültesinin sonra Fen Edebiyat fakültesinin levhalarını göreceksiniz. Fen edebiyat fakültesi levhasının arkasından ilerlerseniz amfiyi göreceksiniz.

Görev-9: Eğitim fakültesinde eğitim bilimlerinin bulunduğu kata çıkma.

Verilecek cevap: (Merkez nokta gösterilerek(Bu yönde birkaç adım yürüyerek)).

Bu yönde hiç sağa ve sola sapmadan düz ilerleyin. Merkez noktadan sağa sola dönmeden düz ilerleyin. Yolun solundaki kongre merkezini geçtikten sonra bulunduğunuz yolu takip edin. Yolun sağında Mimarlık fakültesinin sonra Eğitim Fakültesinin levhasını göreceksiniz. Eğitim bilimleri bölümü Eğitim fakültesi b-blok 3. Kattadır.

AGENT-4:

Görev-1: Grup çalışma alanında sosyal alanı bulup bir sandalyeye oturma.

Verilecek cevap: (Merkez nokta gösterilerek(Bu yönde bir kaç adım yürüyerek)).

Bu yönde ilerleyin ilk soldan dönüp düz devam edince grup çalışma alanına ulaşacaksınız. Grup çalışma alanı levhasının bulunduğu yönde ilerleyin yol ayrımından düz devam edin. Sağ tarafta sosyal alan levhasını göreceksiniz.

Görev-2: Grup çalışma alanında amfi-tiyatroyu bulup bir mindere oturma.

Verilecek cevap: (Merkez nokta gösterilerek (Bu yönde bir kaç adım yürüyerek)).

Bu yönde ilerleyin ilk soldan dönüp düz devam edince grup çalışma alanına ulaşacaksınız. Grup çalışma alanı levhasının karşısındaki yoldan ilerleyin, merdivenleri inin sol taraftaki sanal sınıfları geçtikten sonra sol tarafta denizin üzerindeki amfi-tiyatroyu göreceksiniz.

Görev-3: Grup çalışma alanında bir sanal sınıfta bir sandalyeye oturma.

Verilecek cevap: (Merkez nokta gösterilerek (Bu yönde bir kaç adım yürüyerek)).

Bu yönde ilerleyin ilk soldan dönüp düz devam edince grup çalışma alanına ulaşacaksınız. Grup çalışma alanı levhasının karşısındaki yoldan ilerleyin, merdivenleri inin sol taraftaki sanal sınıfları göreceksiniz.

Görev-4: Medya merkezindeki video galerisini bulup bir videoyu başlatıp durdurma.

Verilecek cevap: (Medya merkezinin içine doğru dönerek).

Şuanda medya merkezi girişindesiniz. Medya merkezine girdikten sonra düz ilerlerseniz fotoğraf galerisinin arkasında video galerisine ulaşırsınız.

Görev-5: Medya merkezinde kafeteryayı bulup bir sandalye veya koltuğa oturma.

Verilecek cevap: (Medya merkezinin içine doğru dönerek).

Şuanda medya merkezi girişindesiniz. Medya merkezine girdikten sonra düz ilerlerseniz sırasıyla fotoğraf galerisine, video galerisine ardından kafeterya ve diskoya ulaşırsınız.

Görev-6: Kongre merkezini bulup bir sandalyeye oturma.

Verilecek cevap: (Merkez nokta gösterilerek (Bu yönde bir kaç adım yürüyerek)).

Bu yönde ilerleyin, ilk sağdan dönün, yolun solunda kongre merkezini göreceksiniz.

Görev-7: Mimarlık Fakültesinde endüstri ürünleri tasarımı bölümünün bulunduğu kata çıkma.

Verilecek cevap: (Merkez nokta gösterilerek (Bu yönde bir kaç adım yürüyerek)).

Bu yönde ilerleyin, ilk sağdan dönün, yolun solundaki kongre merkezini geçtikten sonra bulunduğunuz yolu takip edin. Yolun sağında Mimarlık fakültesi levhasını göreceksiniz. Endüstri ürünleri tasarımı bölümü Mimarlık Fakültesi b-blok 1. Kattadır.

Görev-8: Fen edebiyat fakültesi amfisini bulup bir sandeleyeye oturma.

Verilecek cevap: (Merkez nokta gösterilerek (Bu yönde bir kaç adım yürüyerek)).

Bu yönde ilerleyin, ilk yol ayrımında hiç bir yöne sapmadan düz devam edin. Yolun sağındaki kongre merkezini geçtikten sonra bulunduğunuz yolu takip edin. Yolun solunda sırasıyla İktisadi ve İdari bilimler fakültesinin sonra Fen Edebiyat fakültesinin levhalarını göreceksiniz. Fen edebiyat fakültesi levhasının arkasından ilerlerseniz amfiyi göreceksiniz.

Görev-9: Eğitim fakültesinde eğitim bilimlerinin bulunduğu kata çıkma.

Verilecek cevap: (Merkez nokta gösterilerek (Bu yönde bir kaç adım yürüyerek)).

Bu yönde ilerleyin, ilk sağdan dönün, yolun solundaki kongre merkezini geçtikten sonra bulunduğunuz yolu takip edin. Yolun sağında Mimarlık fakültesinin sonra Eğitim Fakültesinin levhasını göreceksiniz. Eğitim bilimleri bölümü Eğitim fakültesi b-blok 3. Kattadır.

AGENT-5:

Görev-1 : Grup çalışma alanında sosyal alanı bulup bir sandalyeye oturma.

Verilecek cevap: (Kongre merkezi işaret edilerek (Bu yönde birkaç adım atarak)).

Bu yönde ilerleyin, kongre merkezini geçtikten sonra hiçbir yöne dönmeden düz ilerleyince grup çalışma alanına ulaşmış olacaksınız. Grup çalışma alanı levhasından sonra düz ilerleyin. Yol ayrımından düz ilerleyin sosyal alan levhasını göreceksiniz.

Görev-2: Grup çalışma alanında amfi-tiyatroyu bulup bir mindere oturma.

Verilecek cevap: (Kongre merkezi işaret edilerek (Bu yönde birkaç adım atarak)).

Bu yönde ilerleyin, kongre merkezini geçtikten sonra hiçbir yöne dönmeden düz ilerleyince grup çalışma alanına ulaşmış olacaksınız. Grup çalışma alanı levhasının karşısındanki yoldan ilerleyin, merdivenleri inin sol taraftaki sanal sınıfları geçtikten sonra sol tarafta denizin üzerindeki amfi-tiyatroyu göreceksiniz.

Görev-3: Grup çalışma alanında bir sanal sınıfta bir sandalyeye oturma.

Verilecek cevap: (Kongre merkezi işaret edilerek (bu yönde birkaç adım atarak)).

Bu yönde ilerleyin, kongre merkezini geçtikten sonra hiçbir yöne dönmeden düz ilerleyince grup çalışma alanına ulaşmış olacaksınız. Grup çalışma alanı levhasının karşısındanki yoldan ilerleyin, merdivenleri inin yolun sol tarafında sanal sınıflardan birini göreceksiniz.

Görev-4: Medya merkezindeki video galerisini bulup bir videoyu başlatıp durdurma.

Verilecek cevap: (Kongre merkezi işaret edilerek (Bu yönde birkaç adım atarak)).

Bu yönde ilerleyin, kongre merkezini geçtikten sonra yol ayrımından sola dönüp düz ilerleyince medya merkezine ulaşmış olacaksınız. Medya merkezine girdikten sonra düz ilerlerseniz fotoğraf galerisinin arkasında video galerisine ulaşacaksınız.

Görev-5: Medya merkezinde kafeteryayı bulup bir sandalye veya koltuğa oturma.

Verilecek cevap: (Kongre merkezi işaret edilerek (Bu yönde birkaç adım atarak)).

Bu yönde ilerleyin, kongre merkezini geçtikten sonra yol ayrımından sola dönüp düz ilerleyince medya merkezine ulaşmış olacaksınız. Medya merkezine girdikten sonra düz ilerlerseniz sırasıyla fotoğraf galerisine, video galerisine ardından kafeteryaya ulaşacaksınız.

Görev-6: Kongre merkezini bulup bir sandalyeye oturma.

Verilecek cevap: (Kongre merkezi işaret edilerek (Bu yönde birkaç adım atarak)).

Bu yönde ilerleyin, bulunduğunuz yolun sağında kongre merkezini göreceksiniz.

Görev-7: Mimarlık fakültesinde endüstri ürünleri tasarımı bölümünün bulunduğu kata çıkma.

Verilecek cevap:

Şuanda mimarlık fakültesi önündesiniz. Endüstri ürünleri tasarımı bölümü mimarlık fakültesi b-blok 1. Kattadır.

Görev-8: Fen edebiyat fakültesi amfisini bulup bir sandeleyeye oturma.

Verilecek cevap: (Eđitim fakültesi gösterilerek (Bu yönde birkaç adım yürüyerek)).

Bu yönde ilerleyin bulunduđunuz yoldan ayrılmayın. Yolun sađ tarafında sırasıyla Eđitim, Mühendislik ve Fen edebiyat fakültelerini göreceksiniz. Fen edebiyat fakültesi levhasının arkasından ilerlerseniz amfiyi göreceksiniz.

Görev-9: Eđitim fakültesinde eđitim bilimlerinin bulunduđu kata çıkma.

Verilecek cevap: (Eđitim fakültesi gösterilerek (Bu yönde birkaç adım yürüyerek)).

Bu yönde ilerleyin bulunduđunuz yoldan ayrılmayın. Yolun sađ tarafında eđitim fakültesini göreceksiniz. Eđitim bilimleri bölümü Eđitim fakültesi b-blok 3. Kattadır.

AGENT-6:

Görev-1 : Grup çalışma alanında sosyal alanı bulup bir sandalyeye oturma.

Verilecek cevap: (Mühendislik fakültesi gösterilerek (Bu yönde birkaç adım atarak)).

Bu yolu takip edin, sırasıyla Fen edebiyat fakültesi, iktisadi ve idari bilimler fakültesi ve yolun solundaki kongre merkezini geçip düz ilerleyin. Yol ayrımından sağa dönüp ilerleyince grup çalışma alanına ulaşacaksınız. Grup çalışma alanı levhasından sonra düz ilerleyin. Yol ayrımından düz ilerleyin sosyal alan levhasını göreceksiniz.

Görev-2: Grup çalışma alanında amfi-tiyatroyu bulup bir mindere oturma.

Verilecek cevap: Mühendislik fakültesi gösterilerek (Bu yönde birkaç adım atarak)).

Bu yolu takip edin, sırasıyla Fen edebiyat fakültesi, iktisadi ve idari bilimler fakültesi ve yolun solundaki kongre merkezini geçip düz ilerleyin. Yol ayrımından sağa dönüp ilerleyince grup çalışma alanına ulaşacaksınız. Grup çalışma alanı levhasının karşısındanki yoldan ilerleyin, merdivenleri inin sol taraftaki sanal sınıfları geçtikten sonra sol tarafta denizin üzerindeki amfi-tiyatroyu göreceksiniz.

Görev-3: Grup çalışma alanında bir sanal sınıfta bir sandalyeye oturma.

Verilecek cevap: Mühendislik fakültesi gösterilerek (Bu yönde birkaç adım atarak)).

Bu yolu takip edin, sırasıyla Fen edebiyat fakültesi, iktisadi ve idari bilimler fakültesi ve yolun solundaki kongre merkezini geçip düz ilerleyin. Yol ayrımından sağa dönüp ilerleyince grup çalışma alanına ulaşacaksınız. Grup çalışma alanı levhasının karşısındanki yoldan ilerleyin, merdivenleri inin yolun sol tarafında sanal sınıflardan birini göreceksiniz.

Görev-4: Medya merkezindeki video galerisini bulup bir videoyu başlatıp durdurma.

Verilecek cevap: (Mühendislik fakültesi gösterilerek (Bu yönde birkaç adım atarak)).

Bu yolu takip edin, sırasıyla Fen edebiyat fakültesi, iktisadi ve idari bilimler fakültesi ve yolun solundaki kongre merkezini geçip düz ilerleyin. Yol ayrımından hiç bir yere dönmeden diz devam edince medya merkezine ulaşmış olacaksınız. Medya merkezine girdikten sonra düz ilerlerseniz fotoğraf galerisinin arkasında video galerisine ulaşırsınız.

Görev-5: Medya merkezinde kafeteryayı bulup bir sandalye veya koltuğa oturma.

Verilecek cevap: (Mühendislik fakültesi gösterilerek (Bu yönde birkaç adım atarak)).

Bu yolu takip edin, sırasıyla Fen edebiyat fakültesi, iktisadi ve idari bilimler fakültesi ve yolun solundaki kongre merkezini geçip düz ilerleyin. Yol ayrımından hiç bir yere dönmeden diz devam edince medya merkezine ulaşmış olacaksınız. Medya merkezine girdikten sonra düz ilerlerseniz sırasıyla fotoğraf galerisine, video galerisine ardından kafeteryaya ulaşırsınız.

Görev-6: Kongre merkezini bulup bir sandalyeye oturma.

Verilecek cevap: (Mühendislik fakültesi gösterilerek (Bu yönde birkaç adım atarak)).

Bu yolu takip edin, sırasıyla Fen edebiyat fakültesi, iktisadi ve idari bilimler fakültesini geçip bulunduğunuz yolu takip edin, yolun solundaki kongre merkezini göreceksiniz.

Görev-7: Mimarlık fakültesinde endüstri ürünleri tasarımı bölümünün bulunduğu kata çıkma.

Verilecek cevap: (Eğitim fakültesi gösterilerek (Bu yönde birkaç adım yürünerek)).

Bu yönde ilerleyin. Yolun solunda sırasıyla eğitim fakültesini sonra mimarlık fakültesini göreceksiniz. Endüstri ürünleri tasarımı bölümü mimarlık fakültesi b-blok 1. Kattadır.

Görev-8: Fen edebiyat fakültesi amfisini bulup bir sandeleyeye oturma.

Verilecek cevap: (Mühendislik fakültesi gösterilerek (Bu yönde birkaç adım atarak)).

Bu yolu takip edin, Fen edebiyat fakültesine ulaşırsınız. Fen edebiyat fakültesi levhasının arkasından ilerlerseniz amfiyi göreceksiniz.

Görev-9: Eğitim fakültesinde eğitim bilimler bölümünün bulunduğu kata çıkma.

Verilecek cevap: (Eğitim fakültesi gösterilerek (Bu yönde birkaç adım yürünerek)).

Bu yönde ilerleyin. Yolun solunda eğitim fakültesini göreceksiniz. Eğitim bilimleri bölümü b-blok 3.kattadır.

AGENT-7:

Görev-1: Grup çalışma alanında sosyal alanı bulup bir sandalyeye oturma.

Verilecek cevap: (Kongre merkezi gösterilerek (Bu yönde birkaç adım atarak)).

Buyolun takip edin, yolun solundaki kongre merkezini geçip düz dema edin. Yol ayırımından sağa dönüp ilerleyince grup çalışma alanına ulaşacaksınız. Grup çalışma alanı levhasından sonra düz ilerleyin. Yol ayırımından düz ilerleyin sosyal alan levhasını göreceksiniz.

Görev-2: Grup çalışma alanında amfi-tiyatroyu bulup bir mindere oturma.

Verilecek cevap: (Kongre merkezi gösterilerek (Bu yönde birkaç adım atarak)).

Buyolun takip edin, yolun solundaki kongre merkezini geçip düz dema edin. Yol ayırımından sağa dönüp ilerleyince grup çalışma alanına ulaşacaksınız. Grup çalışma alanı levhasının karşısındaki yoldan ilerleyin, merdivenleri inin sol taraftaki sanal sınıfları geçtikten sonra sol tarafta denizin üzerindeki amfi-tiyatroyu göreceksiniz.

Görev-3: Grup çalışma alanında bir sanal sınıfta bir sandalyeye oturma.

Verilecek cevap: (Kongre merkezi gösterilerek (Bu yönde birkaç adım atarak)).

Buyolun takip edin, yolun solundaki kongre merkezini geçip düz dema edin. Yol ayırımından sağa dönüp ilerleyince grup çalışma alanına ulaşacaksınız. Grup çalışma alanı levhasının karşısındaki yoldan ilerleyin, merdivenleri inin yolun sol tarafında sanal sınıflardan birini göreceksiniz.

Görev-4: Medya merkezindeki video galerisini bulup bir videoyu başlatıp durdurma.

Verilecek cevap: (Kongre merkezi gösterilerek (Bu yönde birkaç adım atarak)).

Buyolun takip edin, yolun solundaki kongre merkezini geçip düz dema edin. Yol ayırımından hiçbir yere dönmeden düz ilerleyince medya merkezine ulaşacaksınız. Medya merkezine girdikten sonra düz ilerlerseniz fotoğraf galerisinin arkasında video galerisine ulaşırsınız.

Görev-5: Medya merkezinde kafeteryayı bulup bir sandalye veya koltuğa oturma.

Verilecek cevap: (Kongre merkezi gösterilerek (Bu yönde birkaç adım atarak)).

Buyolun takip edin, yolun solundaki kongre merkezini geçip düz dema edin. Yol ayırımından hiçbir yere dönmeden düz ilerleyince medya merkezine ulaşacaksınız. Medya merkezine girdikten sonra düz ilerlerseniz sırasıyla fotoğraf galerisine, video galerisine ardından kafeteryaya ulaşırsınız.

Görev-6: Kongre merkezini bulup bir sandalyeye oturma.

Verilecek cevap: (Kongre merkezi gösterilerek (Bu yönde birkaç adım atarak)).

Buyolun takip edin, yolun solundaki kongre merkezini göreceksiniz.

Görev-7: Mimarlık fakültesinde endüstri ürünleri tasarımı bölümünün bulunduğu kata çıkma.

Verilecek cevap: (Fen edebiyat fakültesi gösterilerek (Bu yönde birkaç adım yürüyerek.))

Bu yolu takip edin, yolun solunda sırasıyla; Fen edebiyat fakültesi, mühendislik fakültesi, eğitim fakültesini geçtikten sonra mimarlık fakültesine ulaşacaksınız. Endüstri ürünleri tasarımı bölümü mimarlık fakültesi b-blok 1. Kattadır.

Görev-8: Fen edebiyat fakültesi amfisini bulup bir sandeleyeye oturma.

Verilecek cevap: (Fen edebiyat fakültesi gösterilerek (Bu yönde birkaç adım yürüyerek.))

Bu yolu takip edin, yolun solunda fen edebiyat fakültesine ulaşırsınız. Fen edebiyat fakültesi levhasının arkasından ilerlerseniz amfiyi göreceksiniz.

Görev-9: Eğitim fakültesinde eğitim bilimlerinin bulunduğu kata çıkma.

Verilecek cevap: (Fen edebiyat fakültesi gösterilerek (Bu yönde birkaç adım yürüyerek.))

Bu yolu takip edin, yolun solunda sırasıyla; Fen edebiyat fakültesi, mühendislik fakültesini geçtikten sonra eğitim fakültesine ulaşacaksınız. Eğitim bilimleri bölümü b-blok 3.kattadır.

APPENDIX I

VOICE DIRECTIONS

1. Bu yönde ilerlerseniz grup çalışma alanına ulaşırsınız.

2. Bu yönde ilerlerseniz sanal sınıflara ulaşırsınız.

3. Sağ taraftan ilerlerseniz sırasıyla önce sosyal alan sonra açık dans alanına ulaşırsınız.

Sol taraftan ilerlerseniz grup çalışma binalarına ulaşırsınız.

ve Düz ilerlerseniz amfi tiyatroya ulaşırsınız.

4. Sağ taraftan ilerlerseniz önce sosyal alana sonra açık dans alanına ulaşırsınız. Sol taraftan ilerlerseniz sırasıyla grup toplantı alanlarına, amfi-tiyatroya sonra sanal sınıflara ulaşırsınız.

5. Bu yönde ilerlerseniz sağ tarafta sanal sınıflara sol tarafta ise grup çalışma binalarına ulaşırsınız.

6. Bu yönde ilerlerseniz medya merkezine ulaşırsınız.

7. Şuanda fotoğraf sergisi girişindesiniz. Bu yönde ilerlerseniz sırasıyla önce video galerisine sonra kafe ve diskoya ulaşırsınız.

8-26. Bu yönde ilerlerseniz kongre merkezi ve fakülte binalarına ulaşırsınız.

9. Bu yönde ilerlerseniz sırasıyla önce mimarlık fakültesine, eğitim fakültesine, mühendislik fakültesine, fen edebiyat fakültesine ve iktisadi idari bilimler fakültesine ulaşırsınız.

10. Mimarlık fakültesi a bloktasınız. Bu binanın sağında mimarlık fakültesi b blok solunda kongre merkezi bulunmaktadır.

11. Mimarlık fakültesi b bloktasınız. Bu binanın sağında eğitim fakültesi a blok solunda mimarlık fakültesi a blok bulunmaktadır.

12. Bu yönde ilerlerseniz sırasıyla önce eğitim fakültesine, mühendislik fakültesine, fen edebiyat fakültesine ve iktisadi idari bilimler fakültesine ulaşırsınız.

13. Bu yönde ilerlerseniz mimarlık fakültesine ulaşırsınız.

14. eğitim fakültesi a bloktasınız. Bu binanın sağında eğitim fakültesi b blok solunda mimarlık fakültesi b blok bulunmaktadır.

15. eğitim fakültesi b bloktasınız. Bu binanın sağında mühendislik fakültesi a blok solunda eğitim fakültesi a blok bulunmaktadır.

16. Bu yönde ilerlerseniz sırasıyla önce mühendislik fakültesine, fen edebiyat fakültesine ve iktisadi idari bilimler fakültesine ulaşırsınız.

17. Mühendislik fakültesi a bloktasınız. Bu binanın sağında mühendislik fakültesi b blok solunda eğitim fakültesi b blok bulunmaktadır.

18. Mühendislik fakültesi b bloktasınız. Bu binanın sağında fen edebiyat fakültesi a blok solunda mühendislik fakültesi a blok bulunmaktadır.

19. Bu yönde ilerlerseniz sırasıyla önce fen edebiyat fakültesine ve iktisadi idari bilimler fakültesine ulaşırsınız.

20. Bu yönde ilerlerseniz sırasıyla mühendislik fakültesi, eğitim fakültesi ve mimarlık fakültesine ulaşırsınız.

21. Fen edebiyat fakültesi a bloktasınız. Bu binanın sağında fen edebiyat fakültesi b blok solundamühendislik fakültesi b blok bulunmaktadır.

22. Fen edebiyat fakültesi b bloktasınız. Bu binanın sağında İktisadi idari bilimler fakültesi a blok solunda Fen edebiyat fakültesi a blok bulunmaktadır.

23. Bu yönde ilerlerseniz sırasıyla Fen edebiyat fakültesine, mühendislik fakültesine, eğitim fakültesine ve mimarlık fakültesine ulaşırsınız.

24. Bu yönde ilerlerseniz iktisadi idari bilimler fakültesine ulaşırsınız.

25. İktisadi ve idari bilimler fakültesi a bloktasınız. Bu binanın sağında İktisadi idari bilimler fakültesi b blok solunda Fen edebiyat fakültesi b blok bulunmaktadır.

26. İktisadi ve idari bilimler fakültesi B bloktasınız. Bu binanın sağında kongre merkezi, solunda İktisadi idari bilimler fakültesi a blok bulunmaktadır.

27. Bu yönde ilerlerseniz sırasıyla önce iktisadi idari bilimler fakültesine, Fen edebiyat fakültesine, mühendislik fakültesine, eğitim fakültesine ve mimarlık fakültesine ulaşırsınız.

APPENDIX J

FOLLOWED PATHS BY CONTROL GROUP.

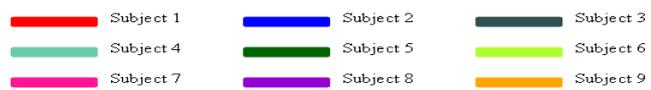
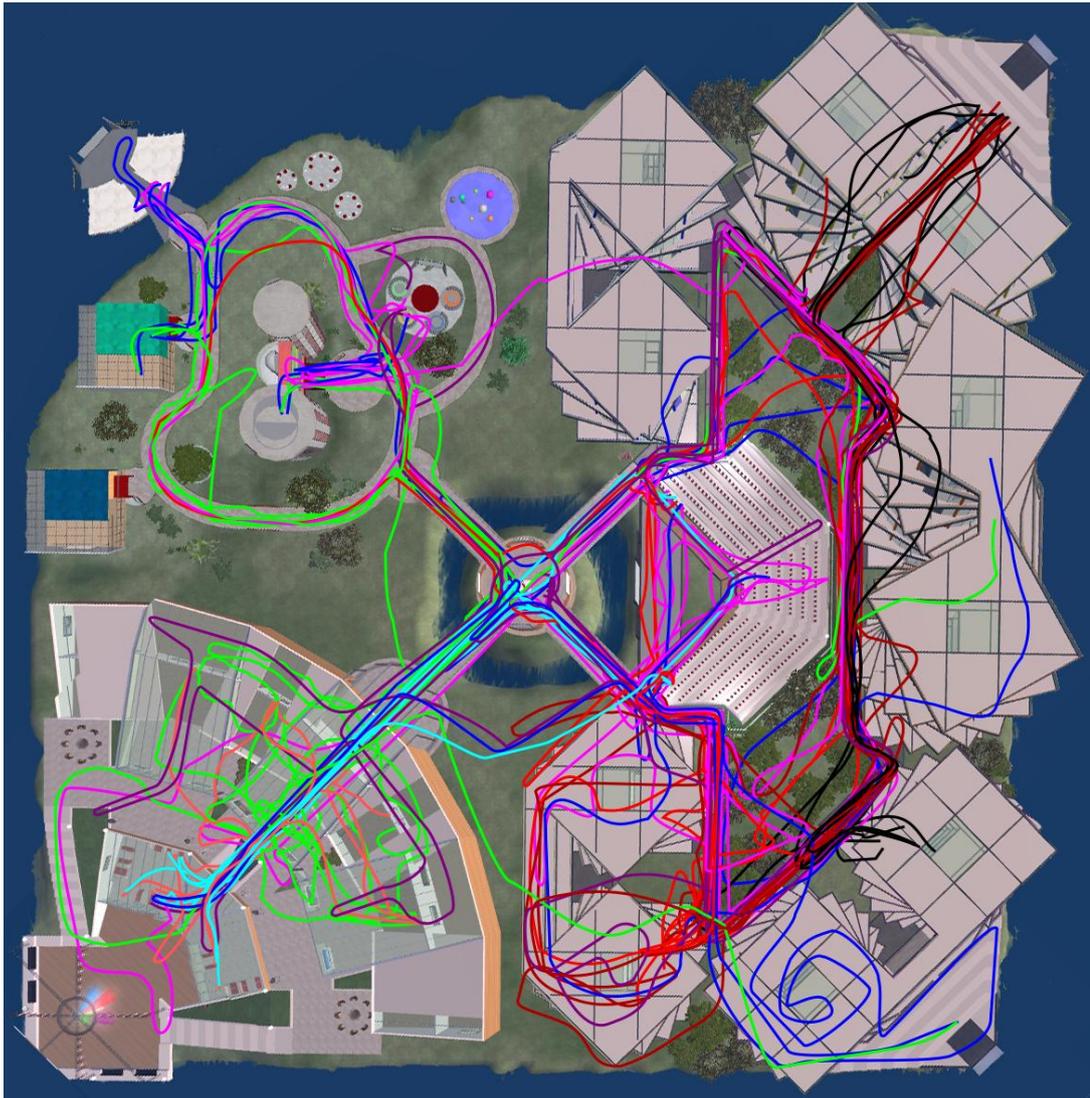


Figure J.1 Legend of control group participants

APPENDIX K

FOLLOWED PATHS BY MAP GROUP.

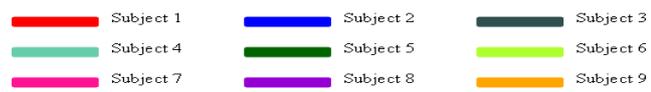
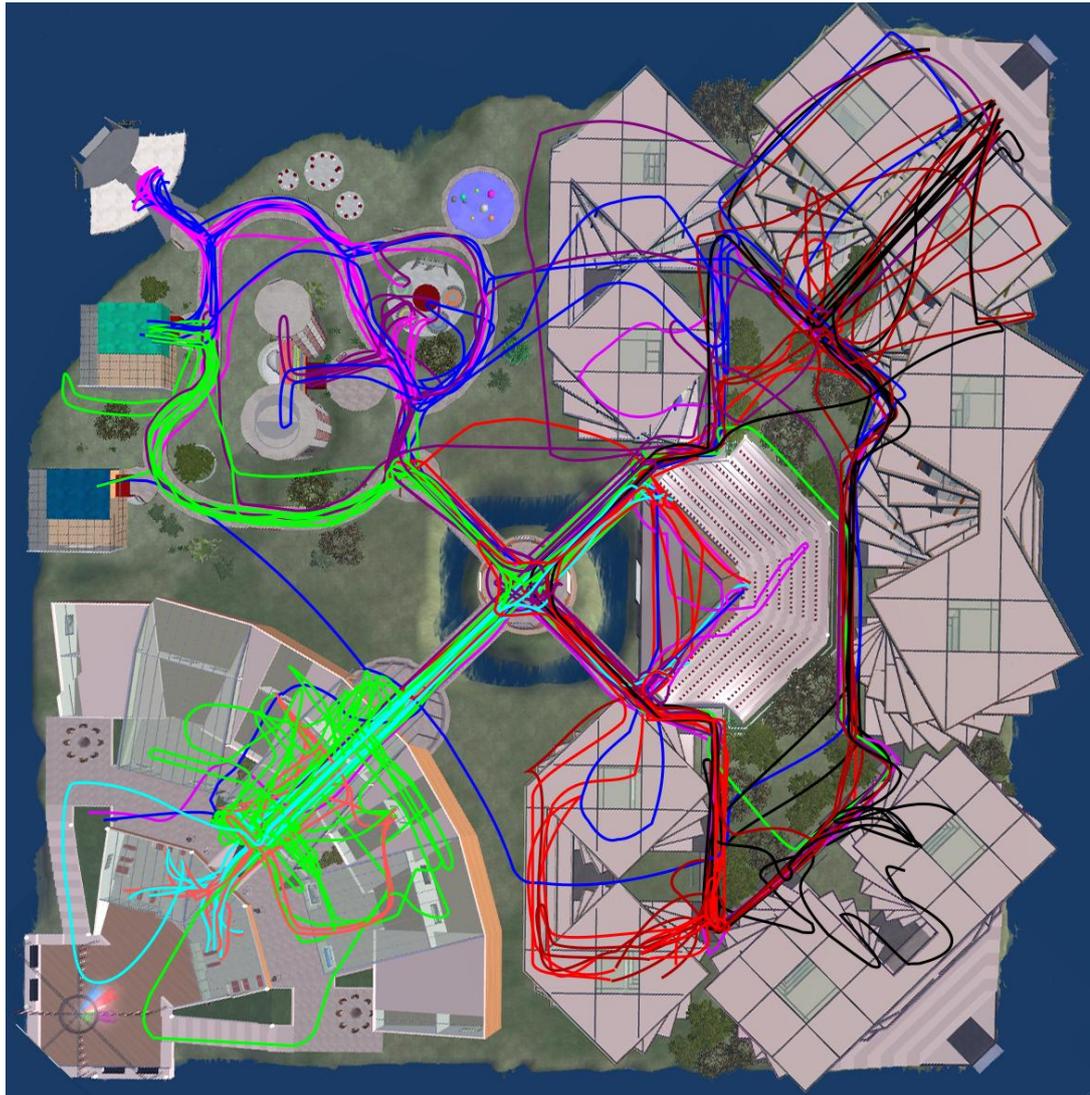


Figure K.1 Legend of map group participants

APPENDIX L

FOLLOWED PATHS BY SIGNBOARD GROUP.

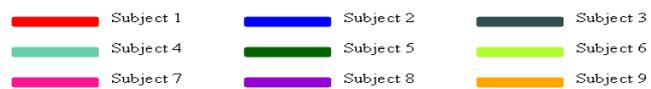
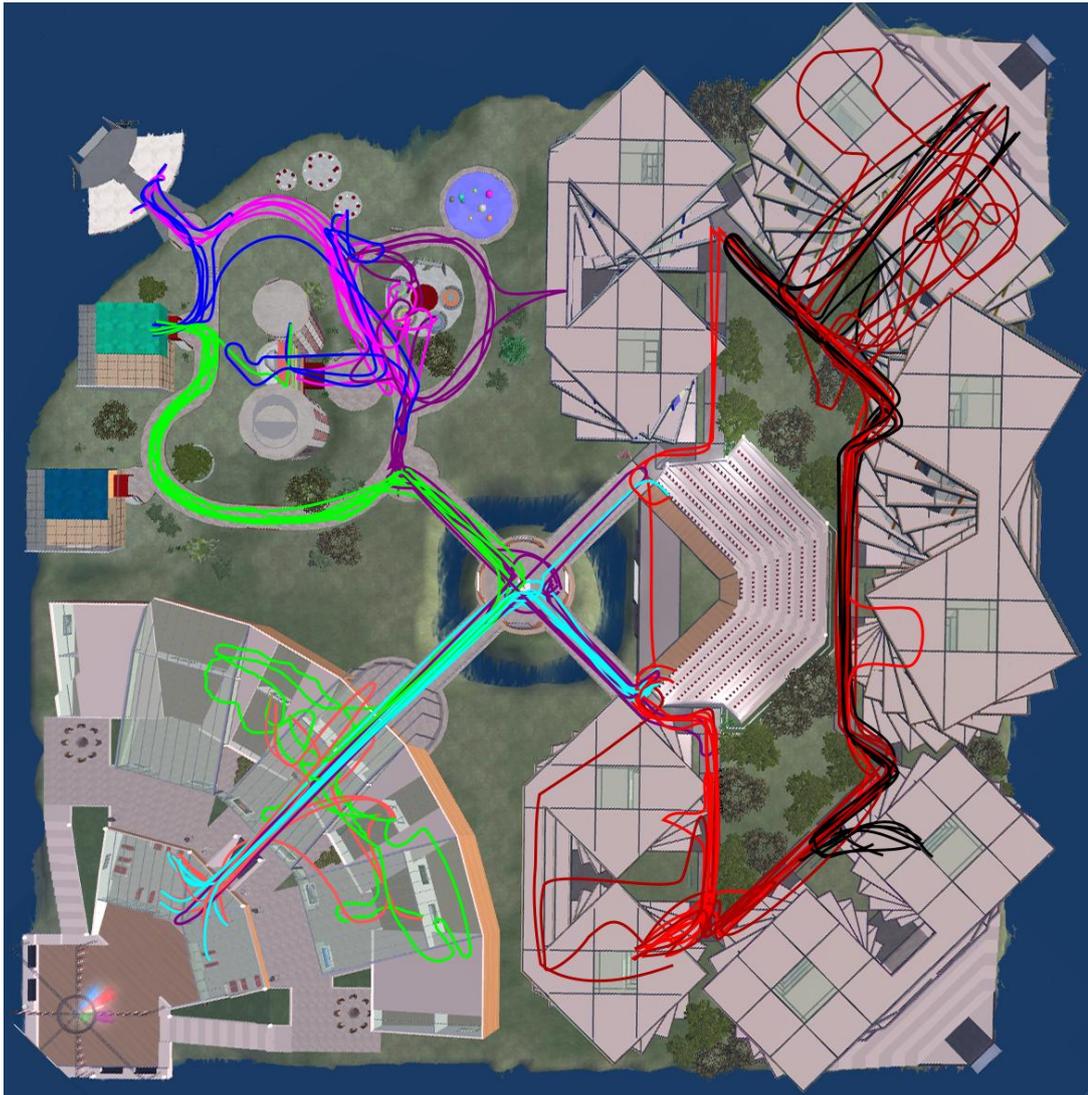


Figure L.1 Legend of signboard group participants

APPENDIX M

FOLLOWED PATHS BY VOICE GROUP.

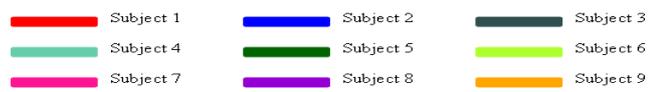
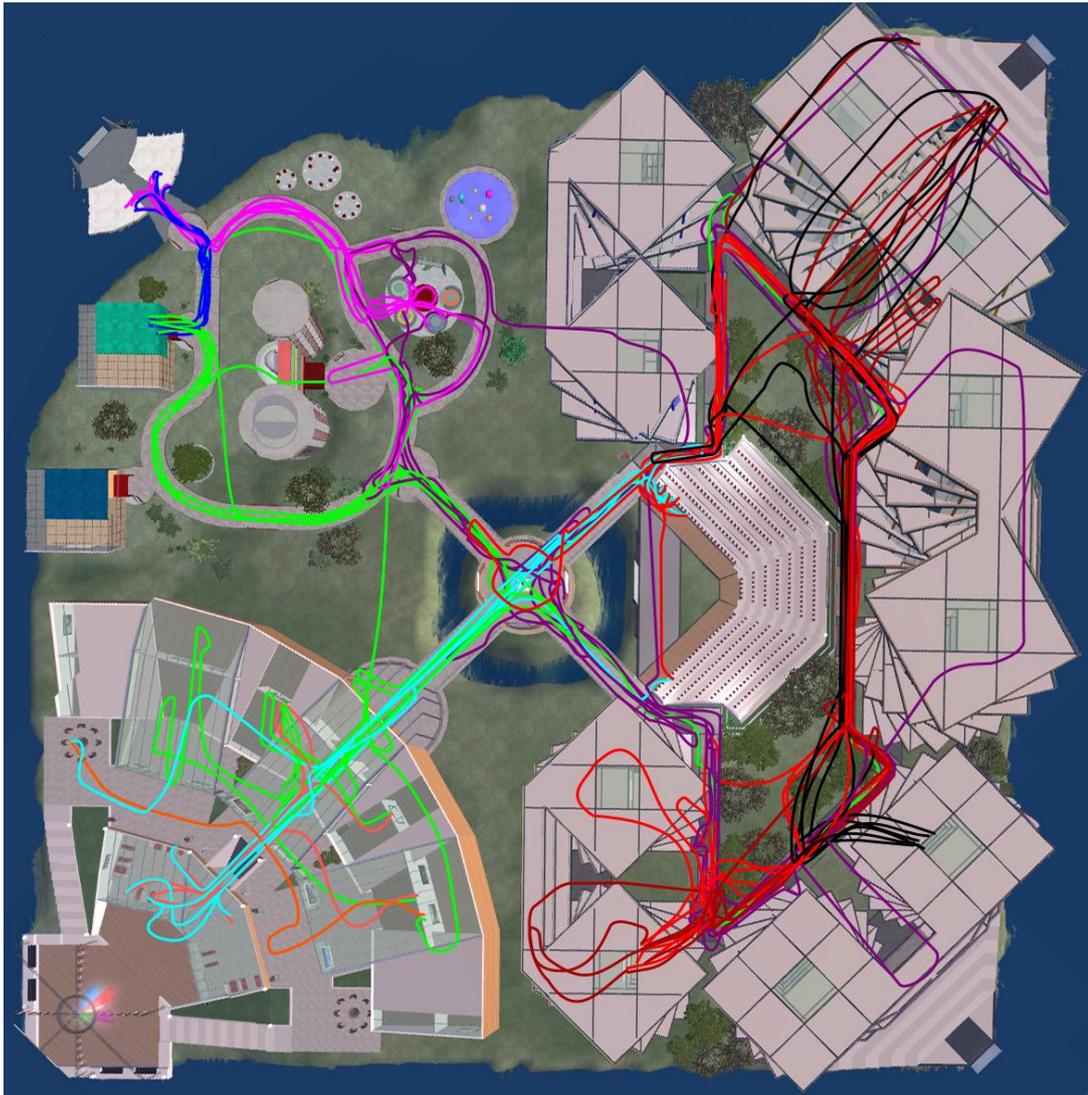


Figure M.1 Legend of voice group participants

APPENDIX N

FOLLOWED PATHS BY AGENT GROUP.

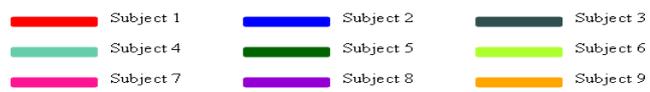
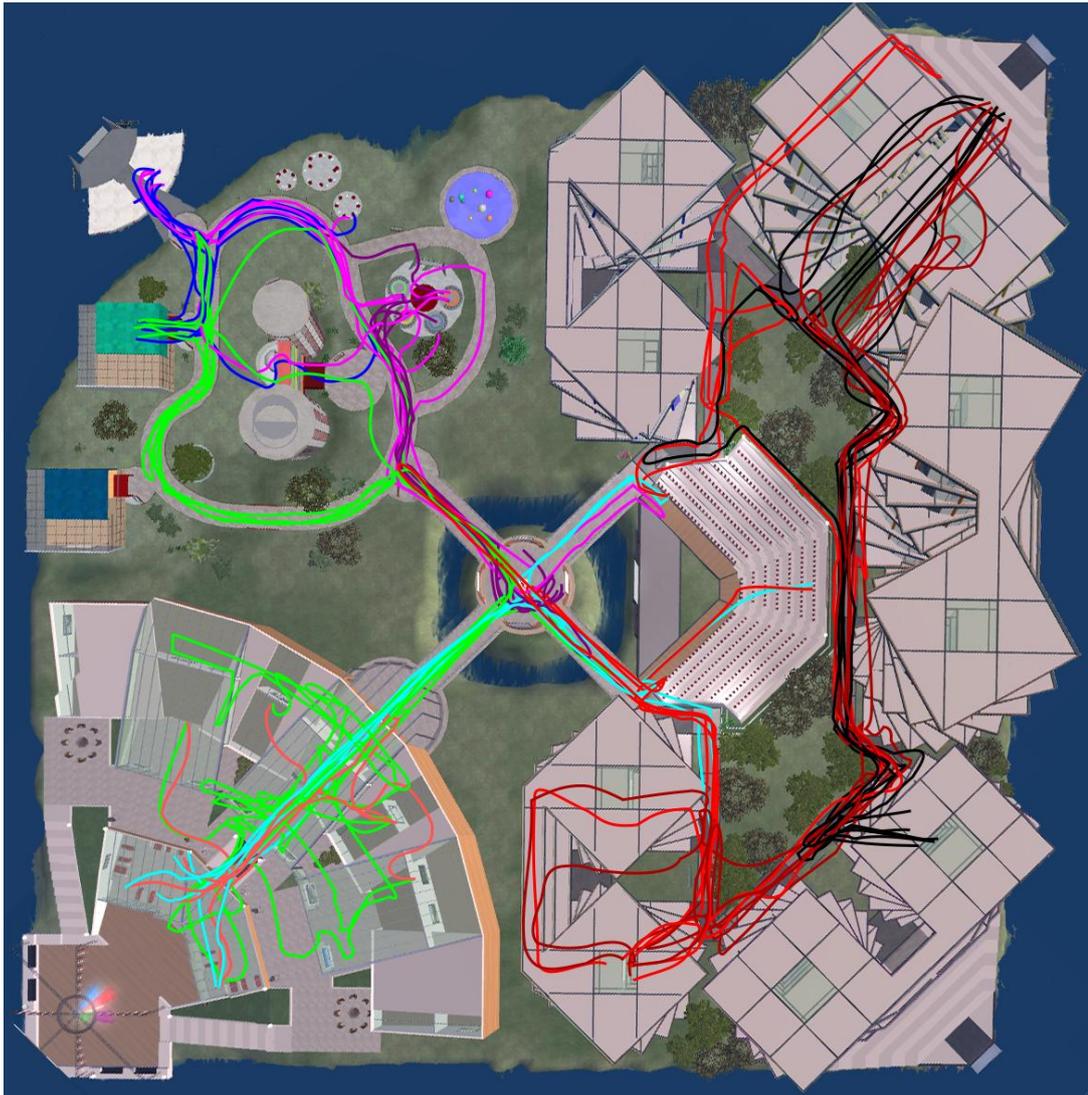


Figure N.1 Legend of agent group participants

APPENDIX O

FOLLOWED PATHS FOR TASK-1.

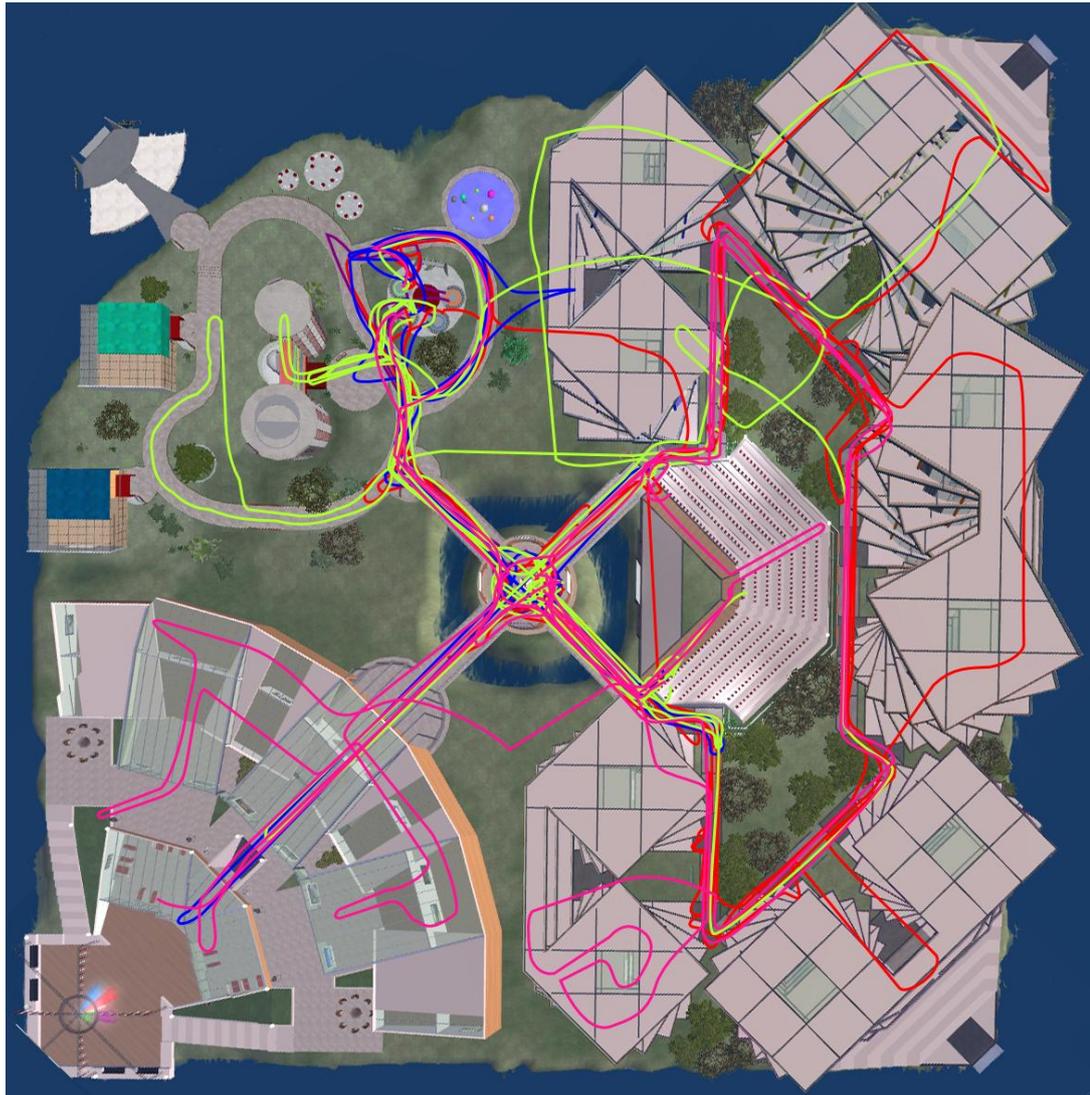


Figure O.1 Legend for task-1 for all participants

APPENDIX P

FOLLOWED PATHS FOR TASK-2.

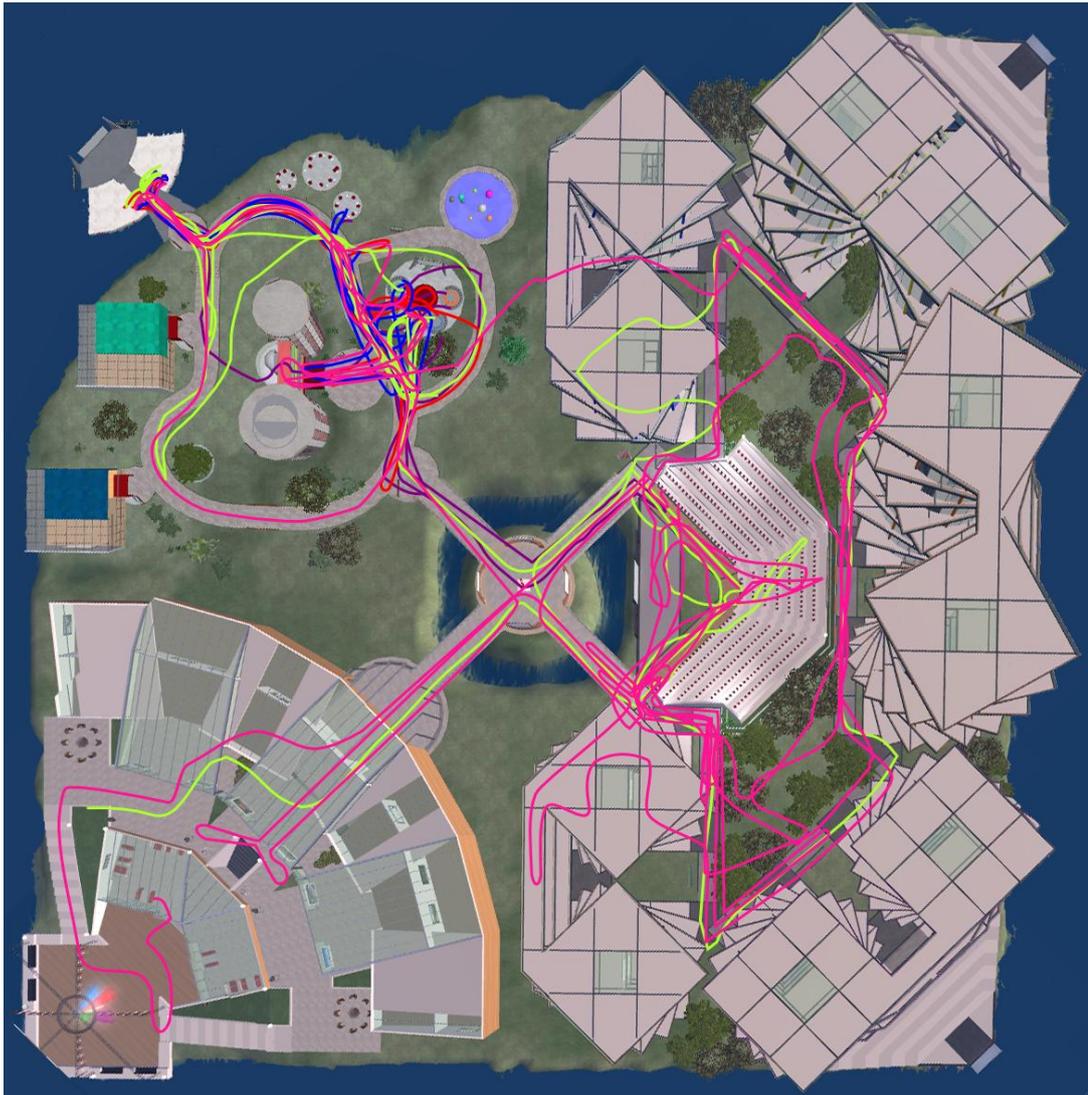


Figure P.1 Legend for task-2 for all participants

APPENDIX Q

FOLLOWED PATHS FOR TASK-3.

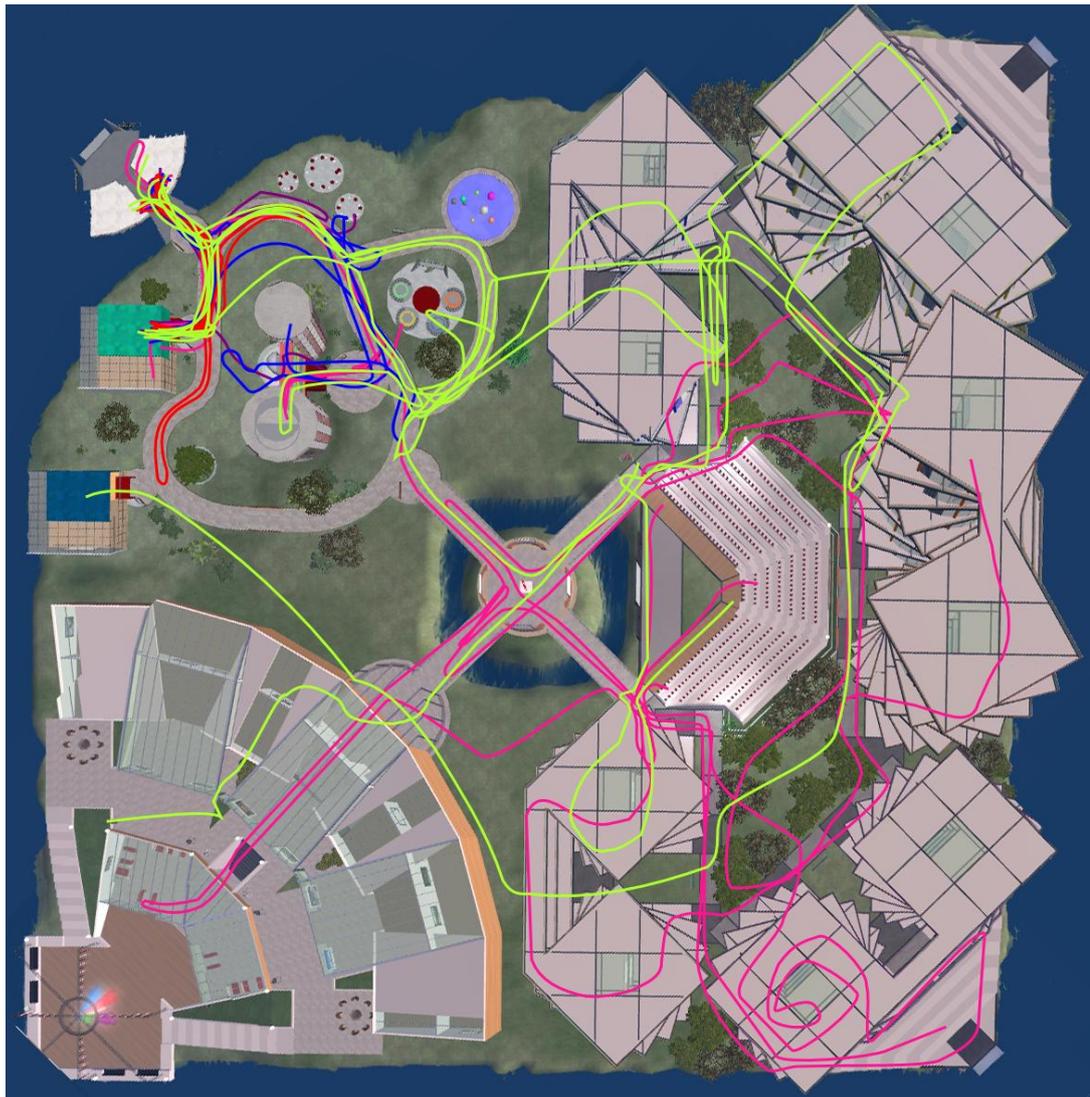


Figure Q.1 Legend for task-3 for all participants

APPENDIX R

FOLLOWED PATHS FOR TASK-4.

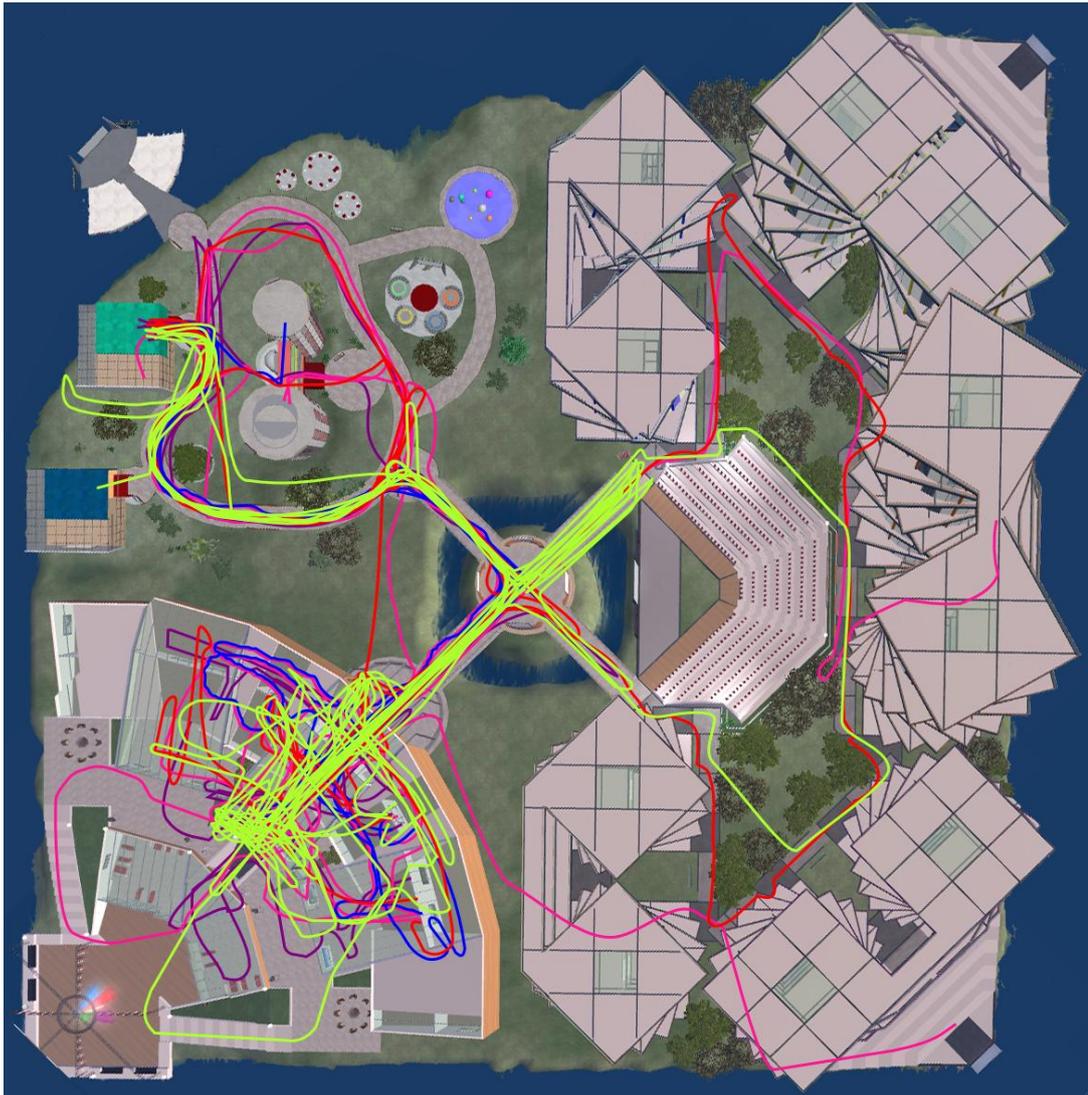


Figure R.1 Legend for task-4 for all participants

APPENDIX S

FOLLOWED PATHS FOR TASK-5.



Figure S.1 Legend for task-5 for all participants

APPENDIX T

FOLLOWED PATHS FOR TASK-6.



Figure T.1 Legend for task-6 for all participants

APPENDIX U

FOLLOWED PATHS FOR TASK-7.

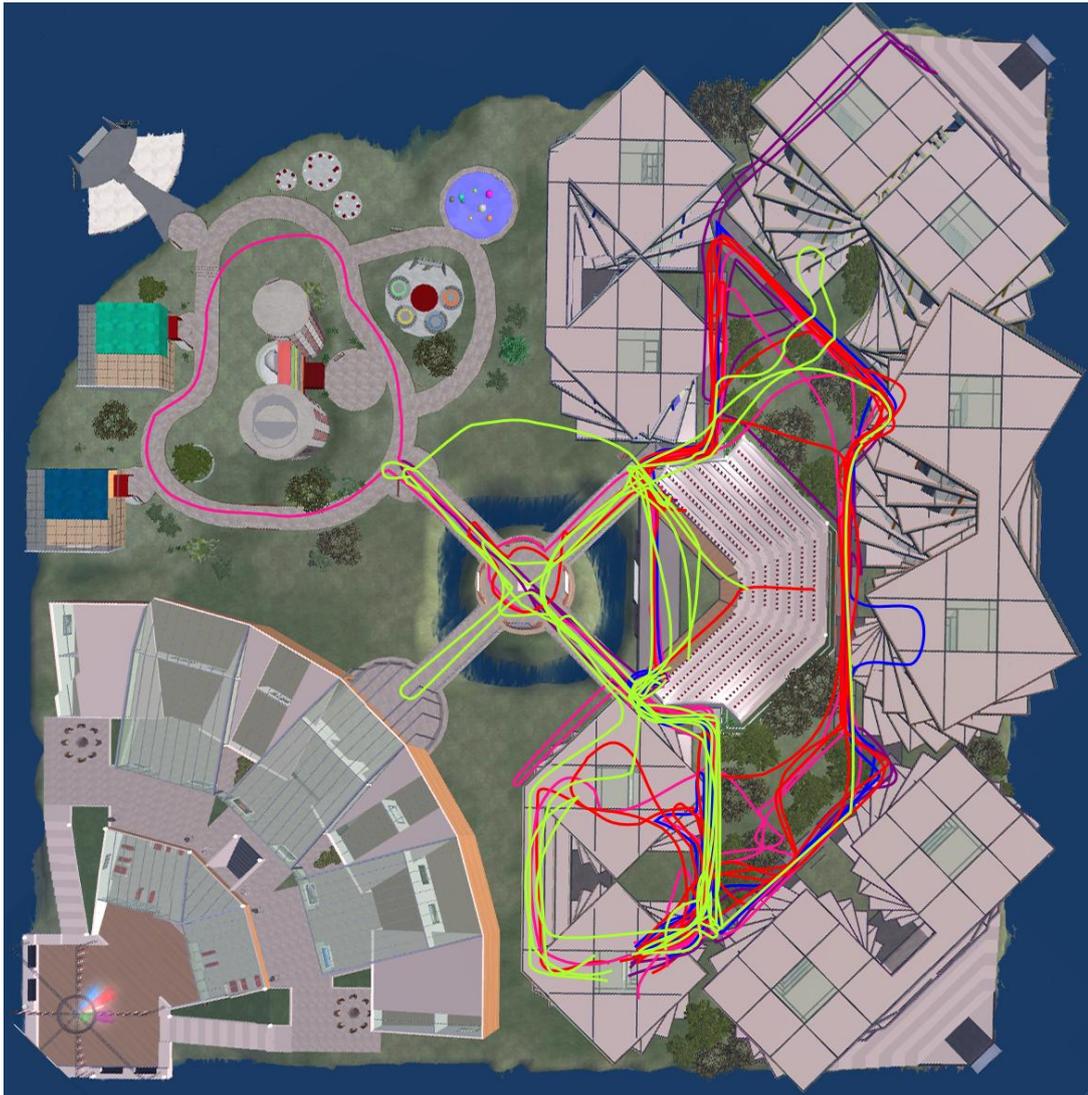


Figure T.1 Legend for task-7 for all participants

APPENDIX V

FOLLOWED PATHS FOR TASK-8.



Figure V.1 Legend for task-8 for all participants

APPENDIX W

FOLLOWED PATHS FOR TASK-9.

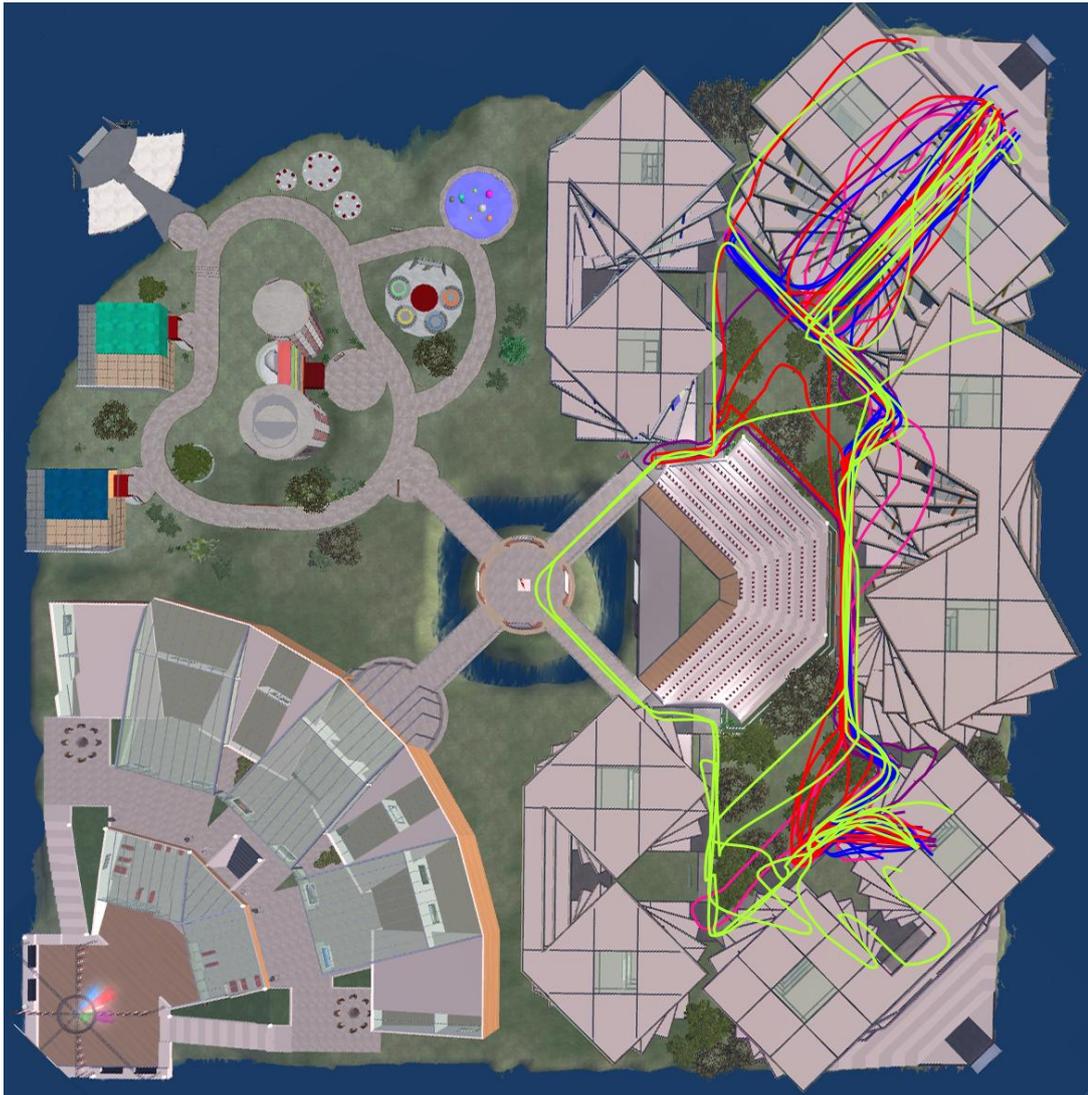


Figure W.1 Legend for task-9 for all participants