USE OF LARGE MULTI TOUCH INTERFACES: A RESEARCH ON USABILITY AND DESIGN ASPECTS

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF INFORMATICS
OF
THE MIDDLE EAST TECHNICAL UNIVERSITY

BY

MEHMET DÖNMEZ

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
IN
THE DEPARTMENT OF INFORMATION SYSTEMS

JUNE 2015

USE OF LARGE MULTI TOUCH INTERFACES:
A RESEARCH ON USABILITY AND DESIGN ASPECTS

Submitted by **MEHMET DÖNMEZ** in partial fulfillment of the requirements for the degree of **Master of Science in Information Systems, Middle East Technical University** by,

Prof. Dr. Nazife Baykal _____
Director, **Informatics Institute**

Prof. Dr. Yasemin Yardımcı Çetin _____
Head of Department, **Information Systems**

Prof. Dr. Kürşat Çağıltay _____
Supervisor,
Computer Education and Instructional Technology, METU

Examining Committee Members:

Prof. Dr. Veysi İşler _____
CENG, METU

Prof. Dr. Kürşat Çağıltay _____
CEIT, METU

Assoc. Prof. Dr. Aysu Betin Can _____
IS, METU

Assoc. Prof. Dr. Banu Günel Kılıç _____
IS, METU

Assist. Prof. Dr. Erol Özçelik _____
CENG, Atılım University

Date: 23.06.2015

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

Name, Last name : Mehmet Dönmez

Signature : _____

ABSTRACT

USE OF LARGE MULTI TOUCH INTERFACES:
A RESEARCH ON USABILITY AND DESIGN ASPECTS

Dönmez, Mehmet
M.S., Department of Information Systems
Supervisor: Prof. Dr. Kürşat Çağıltay

June 2015, 129 Pages

This study explores the design considerations and usability factors of using large multi touch interfaces. During this study, an experimental approach incorporating a large multi touch interfaces environment was used. After the expert analysis and pilot test session, there were end user usability test sessions. During the data collection from both expert and non-expert users, there were interview sessions. After collecting data, two different analysis methods were used, namely, analysis for eye movement data of users and analysis for interviews. After organizing and describing the data, this study revealed that users were generally focusing at the center of the screen while using the large multi touch display. In addition, the most common gestures were Tap gesture and Drag gesture which are single touch input gestures. Besides, it was easy to adapt the system by recalling the previous experiences from mobile devices, and to manage the area and interact with two hands thanks to display size. Furthermore, users were satisfied about using the large multi touch display system.

Keywords: Large multi touch displays, End user usability testing, Eye tracking

ÖZ

BÜYÜK BOYUTLU ÇOKLU DOKUNMATİK ARAYÜZLER:
KULLANILABİLİRLİK VE TASARIM BOYUTLARININ ARAŞTIRILMASI

Dönmez, Mehmet
Yüksek Lisans, Bilişim Sistemleri
Tez Yöneticisi: Prof. Dr. Kürşat Çağıltay

Haziran 2015, 129 Sayfa

Bu çalışmada, büyük boyutlu çoklu dokunmatik arayüzlerdeki dikkate alınması gereken tasarım konuları ve kullanılabilirlik faktörleri incelenmektedir. Bu çalışma sırasında, büyük boyutlu çoklu dokunmatik arayüzleri içeren deneysel yaklaşım kullanılmıştır. Uzman analizi ve pilot test aşamalarından sonra, son kullanıcı kullanılabilirlik test aşamaları yapılmıştır. Uzman kullanıcı ve uzman olmayan kullanıcılardan veri toplanması sırasında, kullanıcılar ile görüşmeler yapılmıştır. Verinin düzenlenmesi ve tanımlanmasından sonra, bu çalışma kullanıcıların büyük boyutlu çoklu dokunmatik ekranı kullanırken genellikle ekranın ortasına odaklandıklarını göstermiştir. Ayrıca, en çok kullanılan dokunmatik hareketler tek dokunma harekeleri olan tıklama ve sürüklemedir. Bunlara ek olarak, kullanıcıların mobil cihazlardaki deneyimlerini kullanarak sisteme adapte olmaları ve ekranın boyutu sayesinde kullandıkları alanı yönetmeleri ve iki el ile etkileşimde bulunmaları kolay olmuştur. Bunların akabinde, büyük boyutlu çoklu dokunmatik ekran kullanımı konusunda kullanıcılar memnun kalmışlardır.

Anahtar Kelimeler: Büyük boyutlu çoklu dokunmatik ekranlar, Son kullanıcı kullanılabilirlik testi, Göz hareketleri takibi

To my family

who believed me and offered me unconditional love throughout my life

ACKNOWLEDGEMENT

Firstly, I would like to give special thanks to my supervisor, Prof. Dr. Kürşat Çağıltay, for his invaluable guidance, encouragement and support during my thesis study. I feel lucky and privileged to have the chance to work with him throughout this thesis study.

I would like to express my deepest gratitude for my father, Süleyman Dönmez and my mother Güniz Dönmez for their unconditional support and endless love throughout my life, and their patience during this thesis study.

I also would like to thank the members of my thesis committee Prof. Dr. Veysi İşler, Assoc. Prof. Dr. Aysu Betin Can, Assoc. Prof. Dr. Banu Günel Kılıç and Assist. Prof. Dr. Erol Özçelik, for their support, comments and advice.

I would like to thank Sibel Doğan and Dr. Serkan Alkan for working with me and keeping me motivated all the time. I also would like to thank my colleague Ayşe Gül Kara Aydemir for her help in coding part. Also, I would like to thank Dr. Murat Duman, Ozan Raşit Yürüm, Ömer Faruk İslim, Selcan Kilis, Okan Arslan and Deniz Selin Uzunosmanoğlu, for their support and advices during my thesis.

I also would like to thank "TÜBİTAK" for its financial support for me achieving a Master of Science Degree.

I would like to thank "T.C. Bilim, Sanayi ve Teknoloji Bakanlığı" and "Simsoft Bilgisayar Teknolojileri Ltd. Şti." for supporting project SANTEZ - 0371.STZ.2013-2, which provides technical infrastructure for my thesis.

Finally, I would like to thank everyone else who supported and helped me during this process.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

HCI: Human Computer Interaction

VLDs: Very Large Displays

LCD: Liquid Crystal Display

LED: Light Emitting Diode

EU 1: Expert User 1

NEU 1: Non-Expert User 1

NEU 2: Non-Expert User 2

NEU 3: Non-Expert User 3

AOI: Area of Interest

TFD: Total Fixation Duration (sec)

TFD/TCTPI: Total Fixation Duration (sec) / Task Completion Time per Interval (sec)

FC: Fixation Count

FC/TCTPI: Fixation Count / Task Completion Time per Interval (sec)

TC: Transition Counts

TC/TCTPI: Transition Counts / Task Completion Time per Interval (sec)

C: Counts

C/TCTPI: Counts / Task Completion Time per Interval (sec)

D: Durations (sec)

D/TCTPI: Durations (sec) / Task Completion Time per Interval (sec)

CHAPTER I

INTRODUCTION

This chapter provides an introduction for the study. This part also includes purpose of the study, significance of the study, research questions and definition of the terms.

1.1 BACKGROUND OF THE STUDY

The increasing use of touch devices has bought significant changes on Human Computer Interaction (HCI). With the usage of touch technology on mobile devices, users have started to use touch technology in their daily lives. Because of this trend, the needs of users have started to change in terms of the display size of devices. Users have started to request for using larger display size which has capability to sense multi touch gestures. According to Martin-Dorta, Saorin, and Contero (2011), touch screen interfaces increase the motivation and satisfaction of the students during the interactive courses.

There are two types of the large screens according to the setup position of the displays, namely, walltop displays and tabletop displays. As it is understandable from the names of the screens, the walltop displays are placed perpendicular to the ground and the tabletop displays are the ones which are parallel to the ground.

There is a wide range of the usage areas of the large multi touch displays like education, military and entertainment. On the other hand, the research about the usability and design of large multi touch displays is weak and not sufficient. There is a need for more research on this area. A possible reason is that the current design of operating systems and applications for devices are more suitable for small screen devices like smart phones, tablet PCs, laptops and desktop PCs whose display sizes are between 3 inches to 27 inches. However, efficiency and effectiveness of the operating systems or design suggestions for such systems should be investigated for large multi touch displays. In this thesis study, a large multi touch display system whose display size is 143 inches (5 X 55 inches) was examined in terms of the usability factors and design suggestions by implementing end user usability tests and interviews with users.

1.2 PURPOSE OF THE STUDY

The purpose of the study is:

1. to investigate the usability factors which influence the usage of very large multi touch displays,

2. to make suggestions for design guidelines of very large multi touch displays.

1.3 SIGNIFICANCE OF THE STUDY

The use of devices with touch ability like smart phones and smart boards is increasing day by day, because using devices by touching is easier and more collaborative than traditional usage of devices by using keys, keyboard, mouse etc. According to Wahab and Zaman (2013), multi touch interactive tables are started to be essential technology for collaborative works. As a consequence of this increase, the demand for larger multi touch devices emerged. It necessitates the studies on this issue.

First of all, there is a need to investigate the usability factors of large multi touch displays, because position of the displays, namely vertical position and horizontal position, needs to be tested from the view of HCI. In addition, the gestures used on large multi touch displays should be different from the usual touch gestures which are used on smaller displays like smart phones or tablet PCs. Besides, user preferences on using large multi touch displays can be different from the user preferences on smaller multi touch displays.

The findings of this study will be important to design of next generation large multi touch displays. Firstly, the findings will be helpful for the manufacturer of the large multi touch display systems in the design stage of these displays. Moreover, since the analyzed gesture suggestions for using on these displays are essential, the findings will contribute to the field of HCI.

1.4 RESEARCH QUESTIONS

This study is guided by the following research questions:

1. What do the usability factors influence participants on using very large multi touch displays?

2. What design suggestions can be given for very large multi touch display based systems?

1.5 DEFINITIONS OF TERMS

Eye Tracking: Eye tracking is the process of electronically locating the point of a person's gaze, or following and recording the movement of the point of gaze.

Touch Screen: A touch screen is an electronic visual display that the user can control through simple or multi touch gestures by touching the screen with a special stylus/pen and-or one or more fingers.

CHAPTER II

LITERATURE REVIEW

This chapter includes five main sections, namely the history of touch displays, larger touch displays and usage, technology of touch displays, gesture standards for touch devices and Very Large Displays (VLDs), and the current VLDs.

2.1 HISTORY OF TOUCH DISPLAYS

At the beginning of the post PC era, the idea of tablet PCs was created well-known patent disputes between two main players, namely Apple and Samsung in the market (Hey & Pápay, 2014). During these lawsuits, Samsung showed Stanley Kubricks' 50 years old "A Space Odyssey" movie as a proof against Apple claims in which a tabletop screen is shown explicitly. Although the tablet PC seen in this scene is no more than an LCD display, it creates the sense of using screen as an input device. Afterwards any developments in interactive large displays were announced "dreams come true" by referencing the movies in which interactive tools depicted.

This shows that there is a breakdown between technological and conceptual development in the subject of multi touch screens. The developmental tracks of tablet computers and touch screen technologies followed different routes before incorporated into a device. For example, the first patent which can be linked to the use of screens as an input devices can be dated back 1915, a century ago (Goldberg, 1915). Pen is the first input tool used instead of keyboard among computers in earlier models at 50s (Dimond, 1957). Although many different models or mediums produced as prototypes for modern touch screens, they won't become a part of daily life until first introduction of iPhone by Apple in 2007 (Grissom, 2008).

After the introduction and the success of the finger controlled touch screens, many models followed iPhone. Today, there are many different types and sizes of touch screens available at the market. It took more than 40 years to develop devices which respond to user touch at table or board size.

According to developing technology and demands of people, touch displays are changing in terms of size, type, purpose of usage in addition to technology behind the screen. At the very beginning of the touch displays, there were capacitive displays (Jain, Bhargava, & Rajput, 2013). It was developed by E.A. Johnson at the Royal Radar Establishment, Malvern, U.K. After that, touch screen technology was improved day by day. In 1982, the first multi touch system was developed in University of Toronto (Buxton, 2009). Afterwards, the first multi

touch display which is based on a transparent capacitive array of touch sensors placed on a Cathode Ray Tube (CRT) was developed by Bob Boie in 1984 (B. Buxton, 2009). After the release of the Nintendo DS in 2004, the popularity of the touch screens started to increase (Jain et al., 2013). With the increase of the popularity of the touch screens, commercial usage of the multi touch screens started to become widespread. One of the leading company was Microsoft Corporation. Microsoft Corporation developed a commercial multi touch system, namely Microsoft Surface (Dietz & Eidelson, 2009). This system is a tabletop computing system and uses infrared (IR) light and series of cameras to detect the interaction of user with the multi touch system. After that, Microsoft PixelSense which has similar technology with Microsoft Surface was released. Microsoft PixelSense uses IR sensors and computer vision to detect the touches. Besides, it has a much thinner tabletop system (Bordin, Zancanaro, & Angeli, 2013).

2.2 LARGER TOUCH DISPLAYS AND USAGE

The early models of the smartphones with touch screens have about 3-4 inch displays. But shortly after, the size of the screens is getting larger as a result of user demand. Today many smartphones come to market with a display about 5 inch or more. Same trend can be tracked in tablet computers also. But, sizes in inches in the market are not satisfactory when multi person interactivity is required.

This trend is consistent with developing technology, people' needs are changing day by day and being more sophisticated, so large wall displays started to enter people' lives and they are taking the place of standard desktop monitors (Malik, Ranjan, & Balakrishnan, 2005). The cause of this change is that there is a need for using sophisticated single-user and multi-user applications on larger place than the standard desktop monitors. In addition, Thompson, Nordin, and Cairns (2012) stated that the more the screen size is larger, the more the involving experience is provided. Besides, large displays with high-resolution help users to reach more information simultaneously and easily (Andrews, Endert, & North, 2010). According to Czerwinski, Tan, and Robertson (2002), larger displays can be used to handle a greater field of view. Czerwinski et al. (2003) stated that working on complex, multiple window tasks with larger displays increases the productivity and satisfaction of users significantly. Also, they reported that users work significantly faster on larger displays while completing multiple step cognitively loaded tasks. Using a large display provides benefits for managing multiple windows by showing on display simultaneously (Bi, Bae, & Balakrishnan, 2014). Besides, working on large display enhances the concentration of the users on the task.

According to Bi et al. (2014), VLDs might be beneficial about ergonomic issues. For example, users are limited to move their heads or to change their sitting position in front of the single monitor usage. On the other hand, users are more relaxed about their body position in front of the large screens.

The factors given above show that, demand for VLDs will continue to increase in following years. Although there are some commercial products with interactive VLDs available as tabletop or walltop in the market already, the empirical research about these products is not common in the literature to provide input to the designers or companies. This study aims to provide explicit cues for the usability and designing issues of very large displays at the end.

The devices with touch sense capability which are used in daily life are smart phones, tablet PCs, laptops and desktop PCs with touch sense displays. The screen sizes of these devices vary from 3 inches to 27 inches when the market comparison is done via the Internet. One of the most important questions for engineers and researchers who are capable of manufacturing these VLDs is who needs a display about 2 meters at diagonal or larger. The answer to this question does not come from the consumers directly. Consumers who want to have a VLD systems know that they need something like VLD, but the details and technical specifications of these systems are not clear to them. Smaller displays are easier to use, but it is hard to handle simultaneous tasks on these displays rather than one task at a time. When the displays are getting larger, many problems occur such as placement of the tasks, unused spaces, low effectiveness and productivity etc. However, these problems do not retain people having large screens.

Today, the use of VLDs is not very common. But probability of meeting with a VLD is getting higher everyday even in a rock bar or a fair. Although they are not frequent today, they will be a part of our daily life soon when the barriers in design, technology and cost are overcomed. The cost of a VLD system is fairly high today, but there are signs that they will be available with different prices and sizes in the market soon.

VLDs have a wide range of areas to be used, namely business, education and public places. Although idea of VLDs is seem to be attractable, the productivity and the effectiveness of these VLDs are not clear yet.

VLDs have many possible applications. Ni et al. (2006) listed eight class for the possible use of VLDs. This is neither final nor exclusive list, but it gives an idea about how wide the areas of VLD use. Despite, they made this classification for only for displays, interactivity in current study can be considered as an asset. The command and control tasks are the first situation that require very high resolution according to Ni et al. (2006). These control centers can be either military or research oriented. Second use of VLDs are design studios such as automobile design in which the product and environment should be seen in its actual size. Geospatial Imagery and Videos; Scientific Visualization; Collaboration and Tele-immersion; Education and Training; Immersive Applications; and Public Information Displays are the other possible applications of VLDs.

2.3 TECHNOLOGY OF TOUCH DISPLAYS

Technology of touch displays has been changed up to nowadays. Jain et al. (2013) state that there are various technologies which are used in touch displays:

2.3.1 CAPACITIVE TOUCH-SCREEN TECHNOLOGY

Capacitive touch-screen technology provides clear display (Kolokowsky & Davis, 2009). It has two types, namely surface capacitance technology and projected capacitance technology. Surface capacitance technology consists of four sensors at the corners of the screen. These sensors identify the touch by checking the changes on the capacitance. In order to use this technology, there is a need to touch the screen via conductive object like a finger. The other type of the capacitive touch-screen technology, projected capacitance technology, has more

advantages than the surface capacitance technology. It provides much more positional accuracy. Besides, it is capable to identify multiple touches simultaneously.

2.3.2 RESISTIVE TOUCH-SCREEN TECHNOLOGY

Resistive touch-screens are the most common and the cheapest touch technology (Kolokowsky & Davis, 2009). This technology is based on pressure on the screen and it can react to touch by a finger or any other object which is a conductive or a non-conductive object.

2.3.3 SURFACE ACOUSTIC WAVE TECHNOLOGY

Surface acoustic wave technology is based on sound waves traveling along the screen (Hao & Kui, 2014). The corruption on the sound waves is used to determine the coordinates of touch point. This technology has shorter reaction time and long service life, but it has high cost and it is difficult to integrate this technology with small sized and medium sized terminals.

2.3.4 INFRARED TOUCH-SCREEN TECHNOLOGY

Infrared (IR) touch technology is based on an IR frame which is an IR emitter at the four sides of the screen (Wei, Liu, He, & Wei, 2011). IR emitter provides horizontal and vertical IR matrix. In order to determine the coordinates (X, Y) of touch point, the controller can calculate the coordinates where the IR matrix is blocked by a finger or any other objects.

2.4 GESTURE STANDARDS FOR TOUCH DEVICES AND VLDs

This part includes two sections, namely gesture standards for touch displays, and gestures in large touch displays.

2.4.1 GESTURE STANDARDS FOR TOUCH DEVICES

There are three main gesture standards for touch devices by companies which has market demand, namely Apple, Android and Microsoft.

As it is shown in the Figure 1, the basic Apple touch screen gestures (Pages for iOS (iPad): Touchscreen basics, n.d.) are tap, two-finger tap, scroll, swipe, flick, drag, select multiple objects, and pinch/stretch.

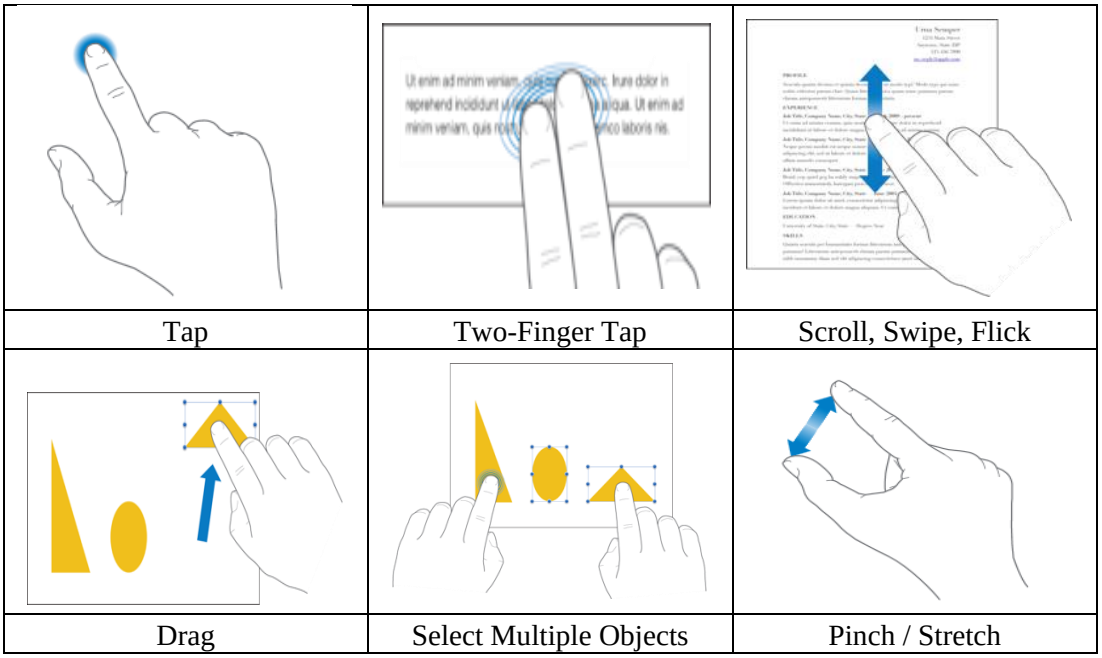


Figure 1 - Apple Touch Screen Gestures (Pages for iOS (iPad): Touchscreen basics, n.d.)

As it is shown in the Figure 2, the core gestures supported by Android (Gestures | Android Developers, n.d.) are touch, long press, swipe or drag, long press drag, double touch, double touch drag, pinch open, and pinch close.

Figure 2 - Android Touch Gestures (Gestures | Android Developers, n.d.)

The main touch gestures of Microsoft (Touch: Swipe, tap, and beyond, n.d.) in the Figure 3 are tap, press and hold, slide, tap-tap-slide, pinch or stretch, rotate, swipe to select, slide to rearrange, and swipe from edge.

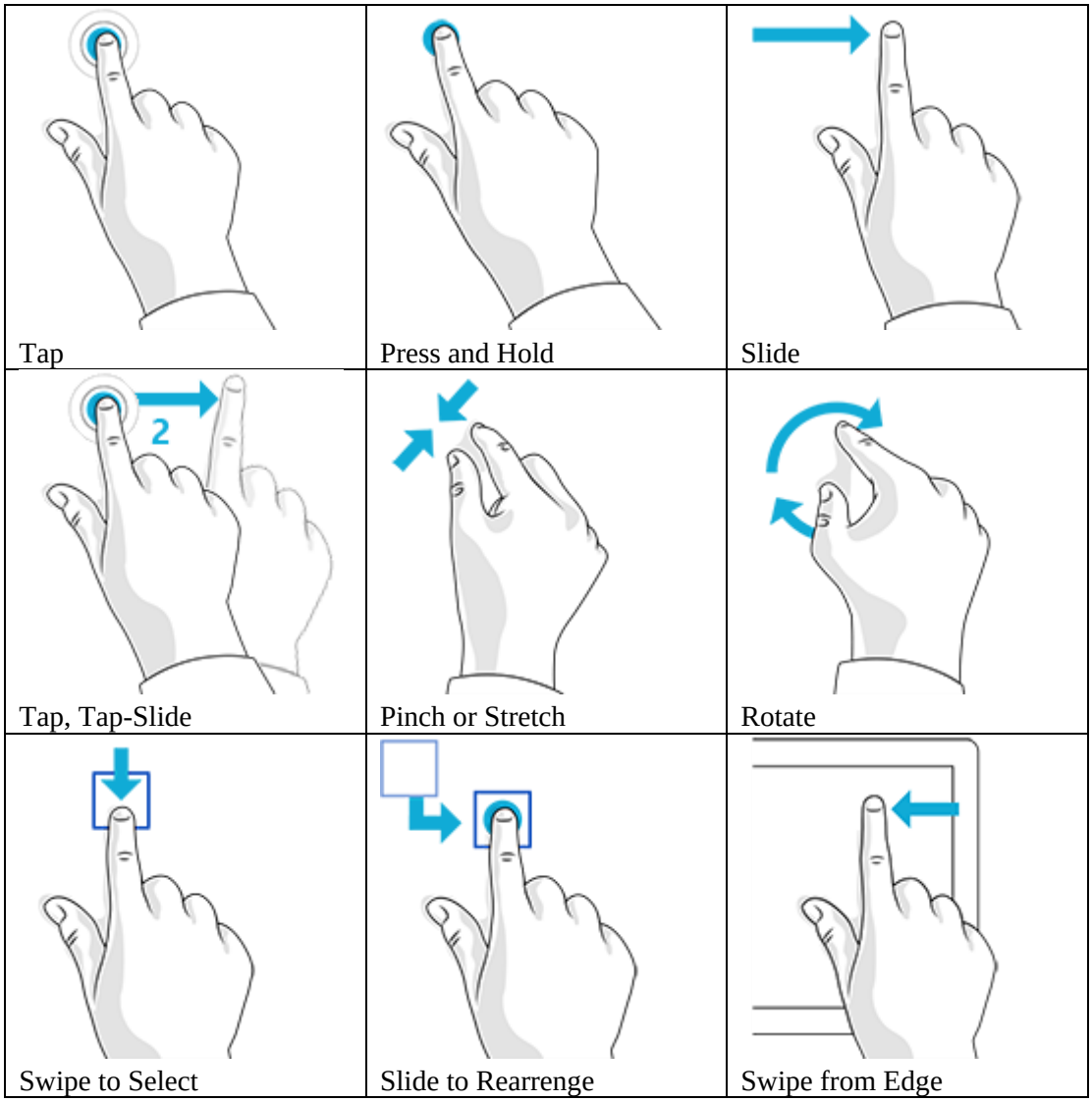
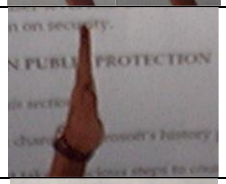
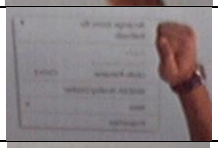
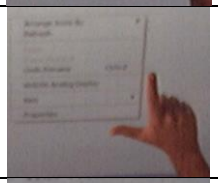
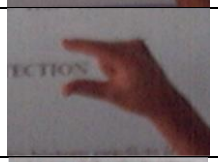


Figure 3 - Microsoft Touch Gestures (Touch: Swipe, tap, and beyond, n.d.)

2.4.2 GESTURES IN LARGE TOUCH DISPLAYS

There are some gesture definitions for VLDs. For example, there is a table (Table 1) about hand shapes and users' frequency of usage on tasks on VLDs by Epps, Lichman, and Wu (2006).

Table 1 - The most common hand shapes and their frequency of usage (Epps et al., 2006)

Hand Shape	Example	% of Total	Main Uses
Index finger		70.1%	Single selection, opening, drawing (>90%), text selection, slider moving (>80%), scrolling (>70%), multiple selection, moving, rotation, zooming, floating menu (>60%), cut/copy (>50%)
Spread hand		20.0%	Rotation (38%), multiple selection (36%), zooming (32%), scrolling (30%), floating menu (28%), drawing (25%)
Flat hand		11.4%	Scrolling (25%), copying (20%), rotation, moving (15%), drawing (13%), zooming (12%), text selection, cut, floating menu (10%)
Grab/Release		4.6%	Cut (25%), copy (13%), moving icons, moving slider (8%)
Vertical hand		1.8%	Cut (8%), text selection, copy (3%)
Fingers together		1.7%	Opening, zooming (5%), text selection, moving, cut, copy, slider moving (3%)
Fist		1.5%	Floating menu (20%), zooming (3%)
“L” shape		1.0%	Floating menu (5%), multiple selection, copy (3%)
“C” shape		0.6%	Floating menu (3%), zooming (2%)
Curved hand		0.6%	Cut (5%), copy (3%)

In addition, there are gesture types (Table 2) provided by Micire, Desai, Courtemanche, Tsui, and Yanco (2009).

Table 2 - Gesture types and description of these gestures (Micire et al., 2009)

	Name	**Description**
Selection	Tap	Single finger taps object to be selected (See Sequence select for multiple taps)
	Double tap	Single finger double taps object to be selected (See Sequence select for multiple taps)
	Lasso	Single finger draws line encompassing objects to be selected
	Meta	Object selected with some external modifier (e.g. Ctrl, Alt)
	Sequence select	Robots selected in a serial fashion (Supersedes Tap and Double Tap)
	Press and hold	Object touched for a duration of longer than 1 second
	Bounding box	Opposite corners of bounding box are shown with fingers
	Palm	Palm of hand placed on object or objects
	Two-finger select	Two fingers on the same hand simultaneously used for selection (Supersedes Tap)
	n-finger	More than two fingers on the same hand used simultaneously for selection (Supersedes Tap)
Position	Drag	Single finger slides across surface to robot destination with immediate lift at end
	Drag and hold	Single finger slides across surface to robot destination with finger hold greater than one second at end
	Waypoint	Tap sequence providing waypoints for robot to follow ending at destination
	Pinch and move	Two finger pinch and then position change to robots' destination
	Flick	One or more fingers placed on robot and fingertip(s) accelerated rapidly in direction of movement
	Path to edge	Finger placed on object and dragged to the edge of screen in direction of movement
	Arrow	Vector gesture terminating in an arrowhead
	Direction segment	Like drag, but smaller segment (vector) not terminating at goal
	Palm drag	Palm placed on object and dragged
	Two-finger drag	Two fingers on the same hand are simultaneously used for drag
	n-finger drag	More than two fingers on the same hand used simultaneously to perform drag
Rotation	Finger rotate	Finger placed on object and fingertip rotated
	Pinch and rotate	Two finger pinch and then rotation change
	Off center rotation	Finger placed on object outside of center of mass and rotated
	C-style rotation	Finger begins in the center of the object, extends outward, and begins rotation
	Palm rotation	Palm placed on object and rotated

	Two-finger rotation	Two fingers from the same hand placed on the object and fingers rotated.
	n-finger rotation	More than two fingers on the same hand used simultaneously to perform rotation
Viewpoint	Pinch	Thumb and finger(s) converging using one hand
	Rev. pinch	Thumb and finger(s) diverging using one hand
	Finger pinch	Two or more fingers converging using two hands - one or more finger per hand
	Rev. finger pinch	Two or more fingers diverging using two hands - one or more finger per hand
	Vanishing point	Hands placed on side parallel to each other and then angled outward
Elements	Menu selection	Menu appears with more than one object property or action
	Button selection	A button selected by pressing on it, allowing for object modification or action
	Keyboard	A keyboard appears for annotation
	Handwriting	Handwriting modifies object
	Voice recognition	Voice recognition modifies object
	Widget	A widget verbally described and interacted via specialized functionality

2.5 THE CURRENT VERY LARGE DISPLAYS (VLDs)

In the HCI literature, there are not many studies about the design of VLDs. One of the aims of the current study is to suggest answers about the design guidelines for VLDs.

Most of the multi touch devices are designed for single person use. But, it should be kept in mind that, single user does not imply single touch. Multi touch concept was developed for single user not for multi user at the beginning. Early multi touch gestures cover finger movements not only on displays but also touch pads etc., they used different media other than displays. The earlier model of multi touch which was touch-sensitive tablet was developed by research groups in the University of Toronto (W. Buxton, Hill, & Rowley, 1985). In Norman's (1988) terminology widely acceptance of multi touch finger movements shows their high affordances when the aim is control on display that is a sign of user centered design. Although some basic models were produced for the market, multi touch is grateful its proliferation to smartphones after millennium.

Although the small displays have primary role in disseminating multi touch gestures, VLDs need new definitions and suggestions to integrate these gestures in those sizes. Multi touch gestures in small displays are finger movements. However, gestures of VLDs should not be in the same manner as small ones. They might include hand and arm gestures in addition to finger ones. Because the proportion between small displays and fingers is quite different from fingers and VLDs. So, the inclusion of other possible body movements to multi touch library makes the interaction richer. But these movements have to have high affordances to be accepted by users. Having high affordance leads faster learning and lower error rates (Norman, 1988). According to Schade (2015), VLDs require to use different gestures rather than using it with

one finger. The reason is that one finger is not applicable for tapping on a big button, using swipe gesture and drag gesture with more effort and physical movement. In parallel, using VLDs requires users to spend more physical effort than using smaller touch screen devices.

Creating a usable interfaces for VLDs, a series of experiments should be conducted. In this study, basic usability methods are integrated with the eye tracking technology to record and analyze bases of user responses. The findings will highlight the users' attitudes and behaviors toward a newly produced VLDs. The data collection procedures will include both observational studies and well-designed experiments. The details of these procedures are given in methodology chapter.

The device developed in this study will create a powerful laboratory environment to test the usability factors of VLDs. Eye tracking technology will provide assistive data to interpret the participants' behaviors during scenarios prepared by experimenters. Thus, the bulk of information embedded in user attitudes, behavior frequencies, self-reports and expert views data will be analyzed to find out the basics of usability factors of VLDs.

CHAPTER III

METHODOLOGY

This chapter provides an overview of the participants, information about study setting, apparatus used during the study, procedure for obtaining the data, data collection, and analysis of the data.

3.1 PARTICIPANTS

While selecting the participants for the study, the aim was to select one expert user (EU) and two non-expert users (NEU). The number of users who know how to use application was limited. The test engineer of the application was selected as expert user. Expert user was using the software for approximately two hours each day during the development process of it. Three of the developers of the application were selected as non-expert users. Non-expert users worked on different stages of the development process of the software. They were not attended the whole process of the development. Therefore, expert user had more comprehensive knowledge of software than non-expert users.

During the interviews, the demographic information of users were gathered. This information is shown in the Table 3.

Table 3 - Demographic Information about Participants

Participants	**Gender**	**Age**	**Undergraduate Degree**	**Occupation**	**Experience Duration**
EU 1	M	26	Electrical and Electronics Engineering	Test Engineer	~ 2 years
NEU 1	M	29	Computer Engineer	Software Engineer	~ 9 years
NEU 2	F	24	Computer Engineer	Software Engineer	~ 2 years
NEU 3	F	24	Computer Engineer	Software Engineer	~ 2 years

3.2 STUDY SETTING

In this study, a very large multi touch display (Figure 4) was placed in a room which has enough size to enable participants to use the device. Then, a software related to military tactical operations was selected and installed for testing the usability factors related to such display

system and offering design suggestions. The reason for selecting this software is that it includes different custom touch gestures to use during the study.

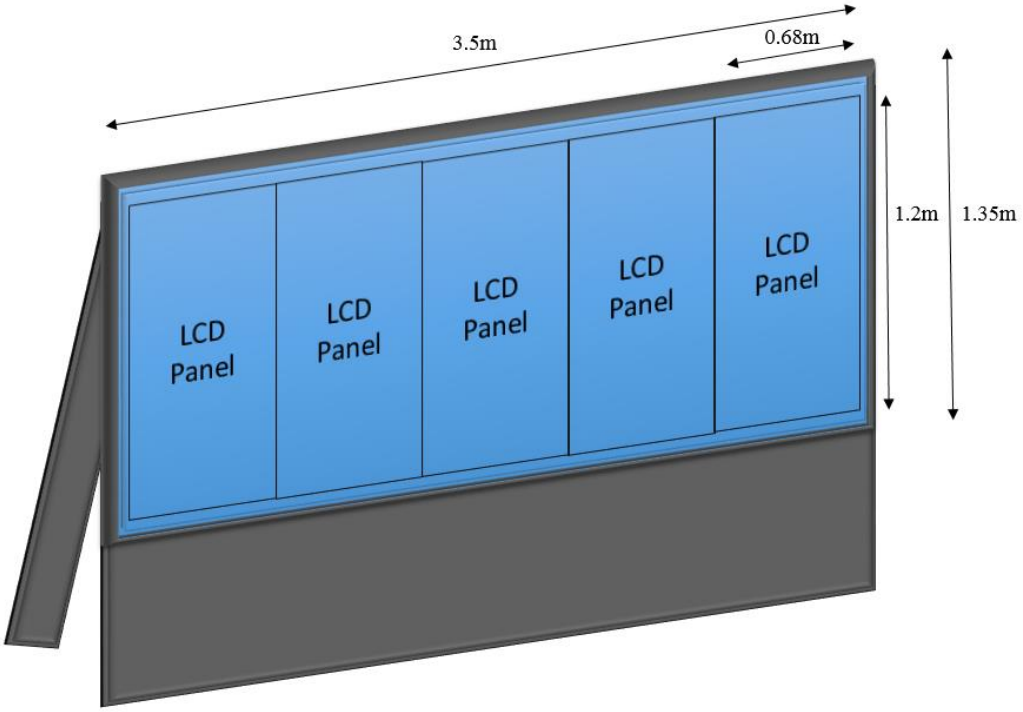


Figure 4 - Design of Very Large Multi Touch Display

In order to identify the tasks to be used in this study, a pilot study was conducted with the guidance of the field expert who has military background. For the pilot study, a scenario was created with the field expert.

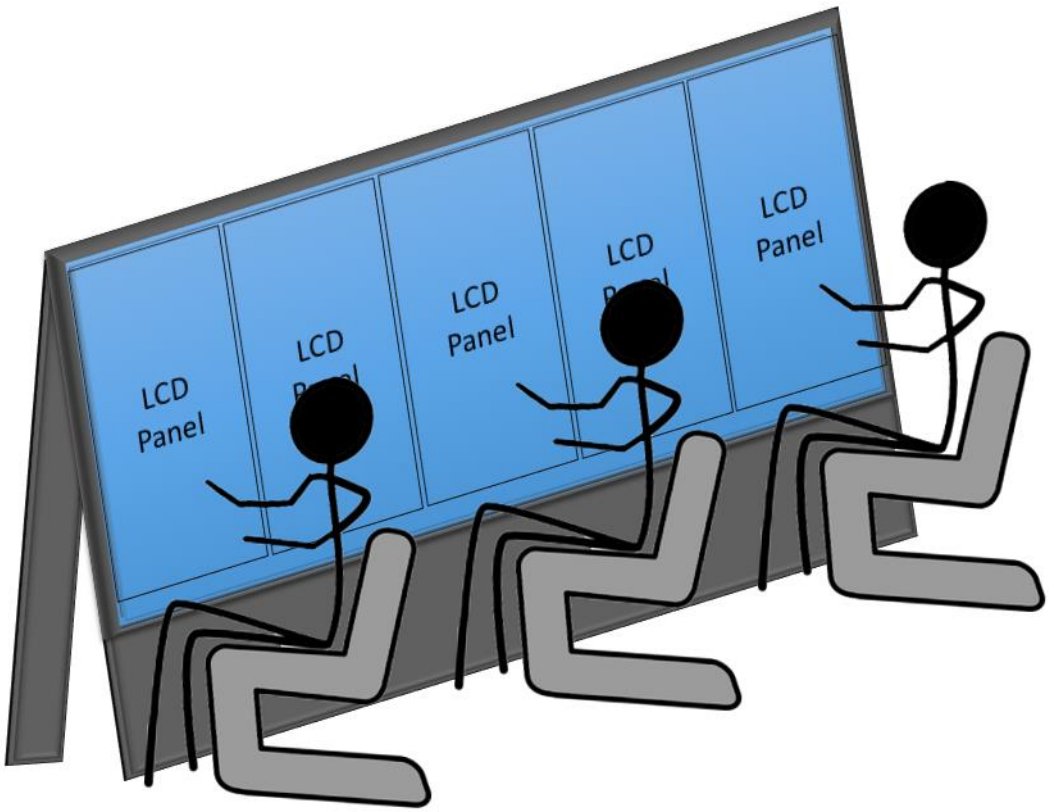


Figure 5 - Pilot Study Setting

The pilot study was conducted with three participants simultaneously (Figure 5). The participants were experts on using the related software so as to determine and clarify the tasks to be used in this study. During the pilot study, video recording was done with two cameras and eye movement data were recorded via glasses type eye tracking devices from two of the three participants. After that, pilot study data were analyzed by the researcher and the task was described in detail step by step for conducting the study with participants. While deciding on tasks, usage of all possible touch screen gestures were taken into consideration.

Later on, the data of actual test were collected from one expert user (EU) and three non-expert users (NEU) who have software developer background. Prior to tests, participants were informed about the tasks and test environment via a short presentation and voluntary participation form. Before the tests, three non-expert users were matched with the expert user in order (Table 4), so the test was conducted 3 times.

Table 4 - The Test Setting

	Participant 1	**Participant 2**
Test Group 1	EU 1	NEU 1
Test Group 2	EU 1	NEU 2
Test Group 3	EU 1	NEU 3

During the tests, participants were asked to sit as it is seen in the Figure 6. Both of the participants were asked to wear glasses type eye tracking devices for recording the eye movement data of them. Also, the test environment was recorded with two video cameras (one from the side of the device and one from the backside of the participants) to identify the usage behaviors of participants. As a result, there were four set of videos; two of them from glasses type eye tracking device and the other two of them from video cameras. Each test session took about 10 minutes to complete by each test group.

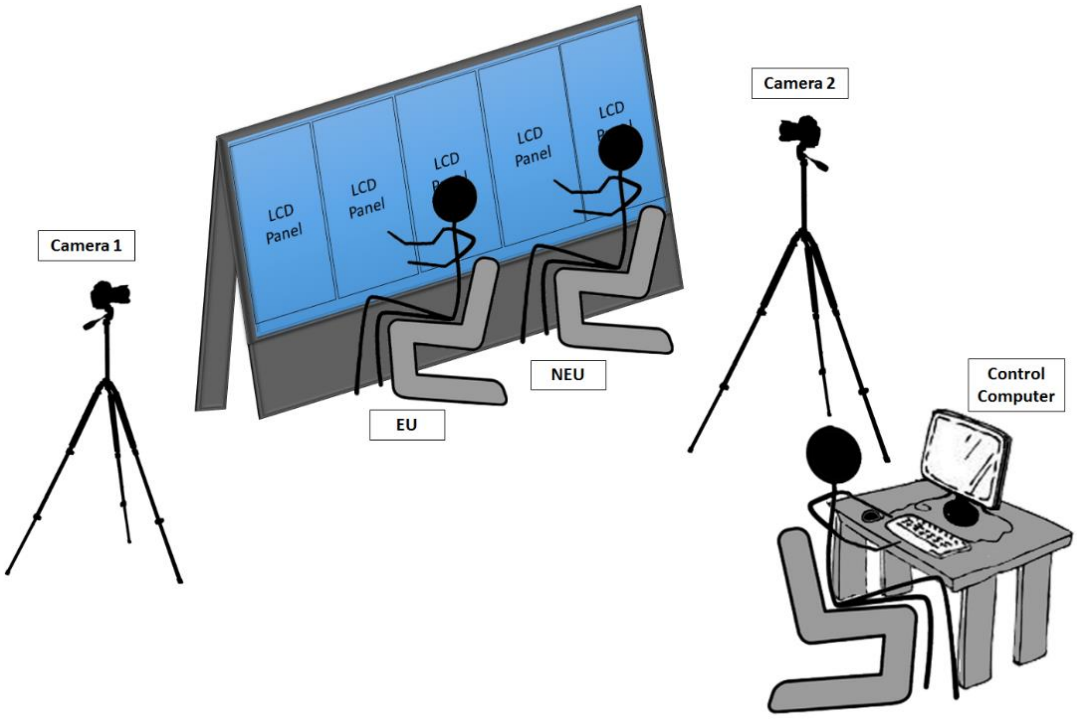


Figure 6 - The Test Setting

During the pilot test and actual tests, there was one more user who plays as smugglers on control computer. This user was changed for each test. In addition, such user used different ways to move inside the border line in order to achieve consistent results from the study.

Subsequent to tests, a short interview around 20 minutes was done with each user about their experiences during the tests. First of all, demographic information about participants was collected. Then, participants were asked to watch their video recordings from their tests and explain what they do and why they do the things during their tests. After that, interview questions were asked to participants to gather information about their experiences. After transcribing interviews, soft copies of the interviews were sent to them for their corrections and approvals.

3.3 APPARATUS

In this study, two Tobii Glasses 1 Eye Tracker device and a large multi touch display were used.

In order to collect eye-movements of the participants, Tobii Glasses 1 Eye Tracker devices were used (Figure 7). These devices track right eye of participants and collect data about where the participants look, how long and how many times they look at which location using the reflector and the infrared detector camera. The data rate of Tobii Glasses 1 Eye Tracker device for tracking is 30 Hertz. It means that the device can capture 30 frames per second. Besides, it captures both video recording and sound recording. The video resolution of its recordings is 640x480 pixels.

Figure 7 - Tobii Glasses 1 Eye Tracker Device

In this study, a large multi touch display was used for providing experiences to participants. The large multi touch display consists of five LCD panels and an IR frame (Figure 8). The brand of the LCD panels is LG. They have 55 inches screen size, 16:9 aspect ratio, 1920x1080 pixels full HD screen resolution, 0.630 mm pixel pitch, 10 milliseconds response time, 5.6 millimeters bezel width, and direct LED panel technology. The IR frame of the system has 143 inches frame size, 32767 x 32767 pixels resolution, finger or object detection capability as touch input, 4 millimeters tempered glass, 50 millimeters width, 14 millimeters thickness, 32 points simultaneous touch detection capability, and 15-22 milliseconds response time.

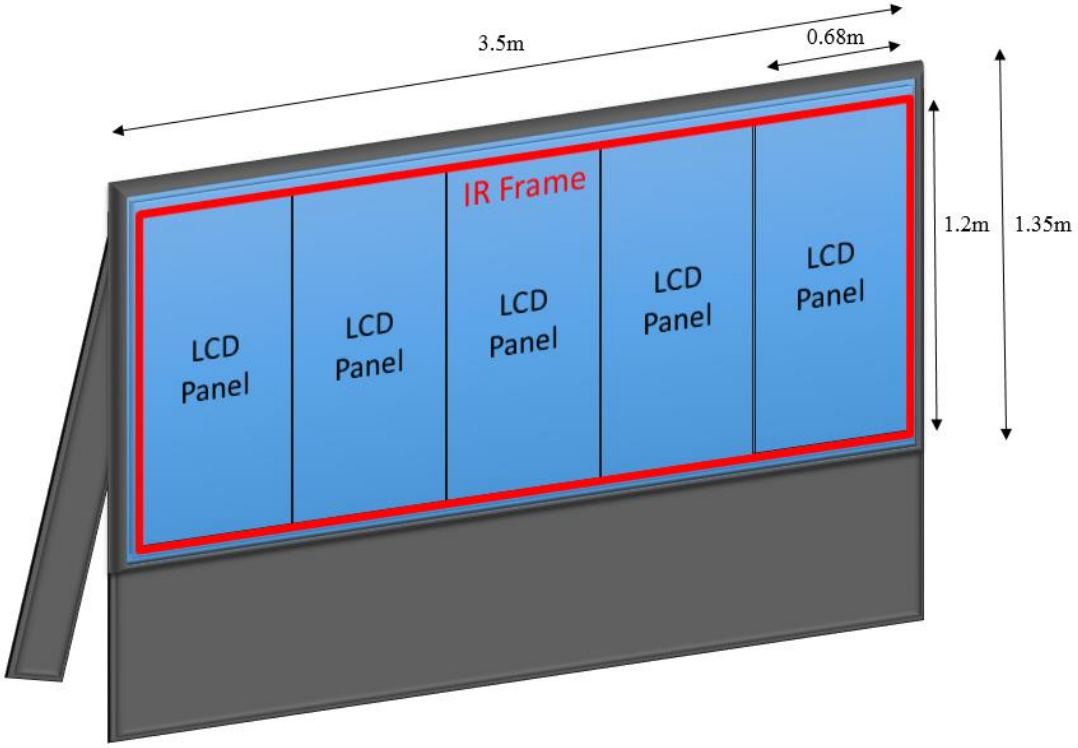


Figure 8 - Large Multi Touch Display

3.4 PROCEDURE

In order to specify the task to use, a meeting was done with an expert. According to the meeting results, a scenario was determined for the tests.

This scenario is a military training task which includes all possible gestures of the application like Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture. It takes approximately 10 minutes to complete the task.

The task consists of three steps. The first step is that two different smugglers, who are controlled by the user on the control computer, enter from the border line by cutting the wires (Figure 9). Each smuggler starts to move inside the border line through different directions. Then, two guardhouses are alarmed about the unauthorized entrance from the border line (Figure 10). As the second step of the task, each of the two users, expert user and non-expert user, selects one of the guardhouses and starts to follow and to catch one of the smugglers. While following the smugglers, users can manage soldiers and vehicles according to their strategy (Figure 11). In addition, there are tools and devices to use during the tracing. As the third and final step of the task, each user arrests and handcuffs one of the smugglers (Figure 12).

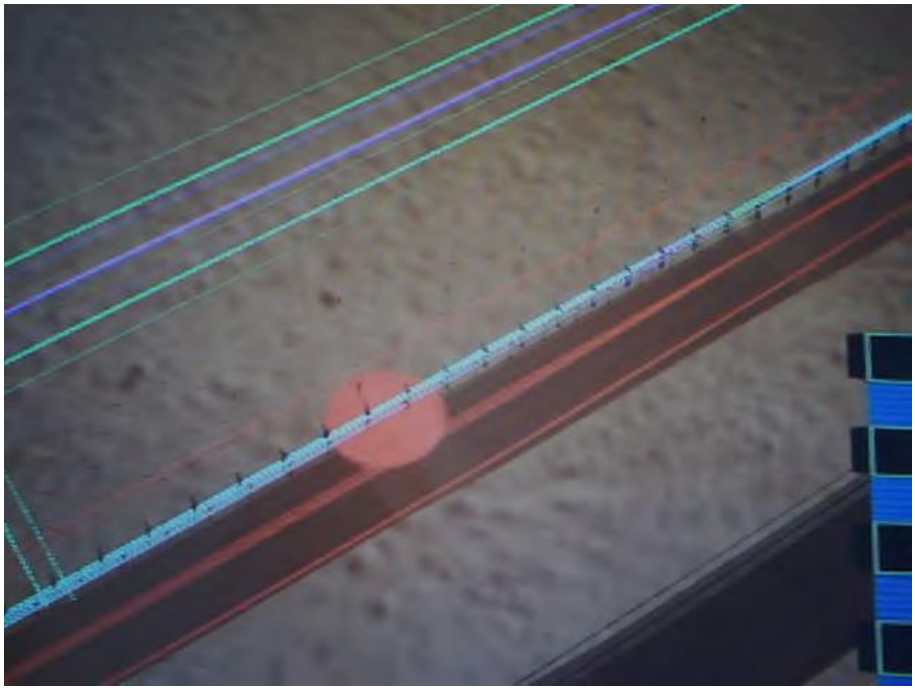


Figure 9 - The First Step of the Task: Cutting the Wires

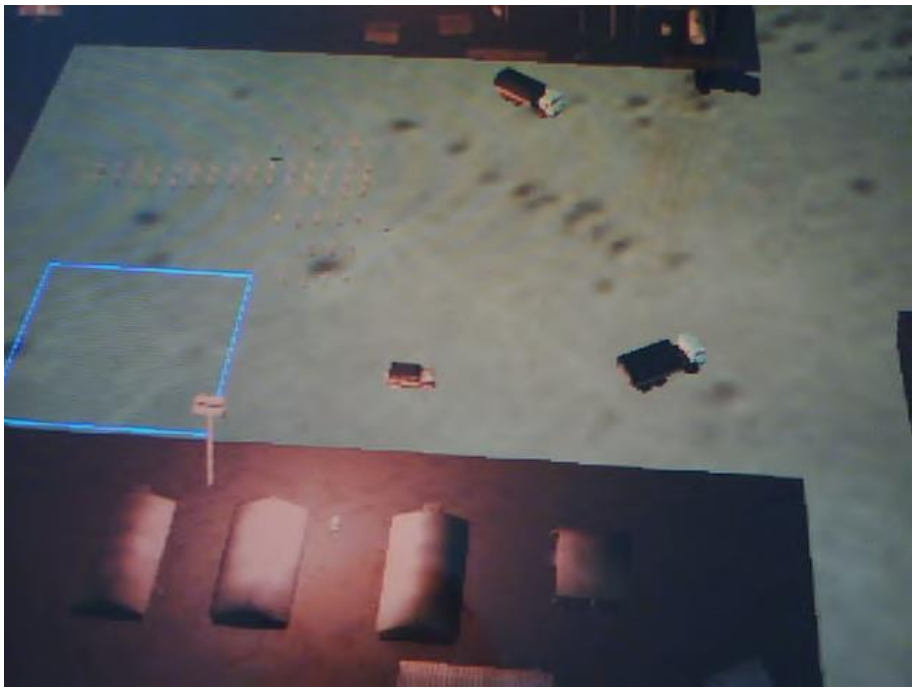


Figure 10 - The First Step of the Task: Alarm on the Guardhouses

Figure 11 - The Second Step of the Task: Interaction with Area

Figure 12 - The Final Step of the Task: Arresting the Smuggler

Users were already aware of the usage of the software about military training, because they are members of the developer team of this software. After defining the task, users were informed about the task and they were asked to complete the task as soon as possible. While users were doing the task, their eye movements were recorded for the analysis of the data in order to interpret their attitudes, behaviors, task completion times, and their successes.

Subsequent to completion of the task, retrospective reviews with users were conducted. Each user watched his/her own video recording with their eye movements which were gathered via the glasses type eye tracking device. While watching, users were asked to explain what and why they were doing during the task.

3.5 DATA COLLECTION

For data collection, two different methods were applied. The first method was end user usability testing. The participants were asked to complete the given task by using the software which was located on the large multi touch display. During the end user usability testing, one expert user (EU) and one non-expert user (NEU) used the software simultaneously. The same test was repeated for three times. Expert user was the same person during the tests and non-expert users were changed for each test. The steps of the task for each test was the same, but there were different options on the software for smugglers and users to move. Because of this, users were acting differently for every usage. In addition, eye movements of both expert user and non-expert user were recorded with glasses type eye tracking device. In addition, users' behaviors were recorded with two video cameras one from back side of the users and one from the left side of the users. Besides, field notes were taken during the experiences of users by the researcher. At the end of the each test, four video records, namely two from glasses type eye tracking device and two from video cameras were gathered for each test. Then, the combination of four video records for each test was created by using a video editing program in order to use during the analysis of the data.

After end user usability testing, the interviews were done with expert user and non-expert users as a second method by taking their voice recordings. At the beginning of the interview session, the retrospective review with each user of Test 1 was done in order to strengthen the data. During the retrospective review, each user of Test 1 was asked to watch his/her own video recording with their eye movements which was gathered via the glasses type eye tracking device and to explain what and why they were doing while using the software on large multi touch display. Subsequent to retrospective review, users were interviewed in order to collect information about their experiences during the usage of the software which was located on a large multi touch display.

3.6 DATA ANALYSIS

The data which were gathered during this study were analyzed in two steps. The types of analysis applied for Test 1, Test 2 and Test 3 are shown in the Table 5. The eye movement data were analyzed for only Test 1 and Test 2. In addition, the reason for applying retrospective review for Test 1 was that there was a need for figuring out the scenario more clearly from the perspective of users. Besides, the eye movement data from Test 1 and Test 2 were enough to present attitudes and behaviors of users. Therefore, Test 3 was applied only for supporting the interview data in order to strengthen the design suggestions for the system.

Table 5 - Analysis Types of the Study

	Eye Movement Data	**Retrospective Review Data**	**Interview Data**
Test 1	X	X	X
Test 2	X		X
Test 3			X

As the first step, the eye movement data which were gathered via glasses type eye tracking device were analyzed for Test 1 and Test 2. Firstly, manual coding was done to identify the users' line of vision. The eye movement recordings of users were collected with 30 Hz data rate. It means that there are the data of viewpoint coordinates for each 33 milliseconds. During the analysis of these data, the video recordings from glasses type eye tracking device were reviewed on the software of such device and coded manually on this software (Figure 13).

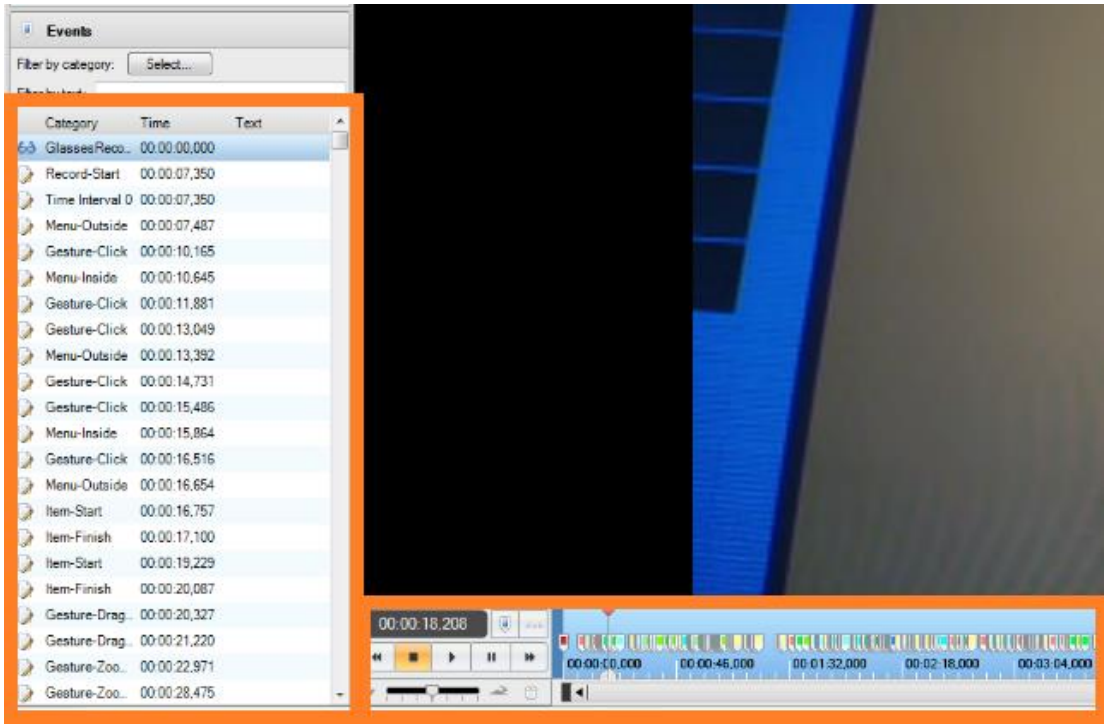


Figure 13 - Manual Coding Environment

This coding was to investigate counts and durations of users' line of vision and gestures performed by users. After the manual coding, the data for each user were divided into 10 equal time intervals in order to examine the data more efficiently. In addition, the video recordings with users' eye movements, which were gathered via the glasses type eye tracking device, were divided into 4 equal Area of Interests (AOIs) as in the Figure 14 in order to analyze the fixation counts and fixation durations of users for each AOI. Later, the data were exported from the software and calculated for each time interval by considering task completion time per interval of users. Besides, gaze plots of users for each time interval were exported as image files. Finally, the results were formatted and described in the results chapter.

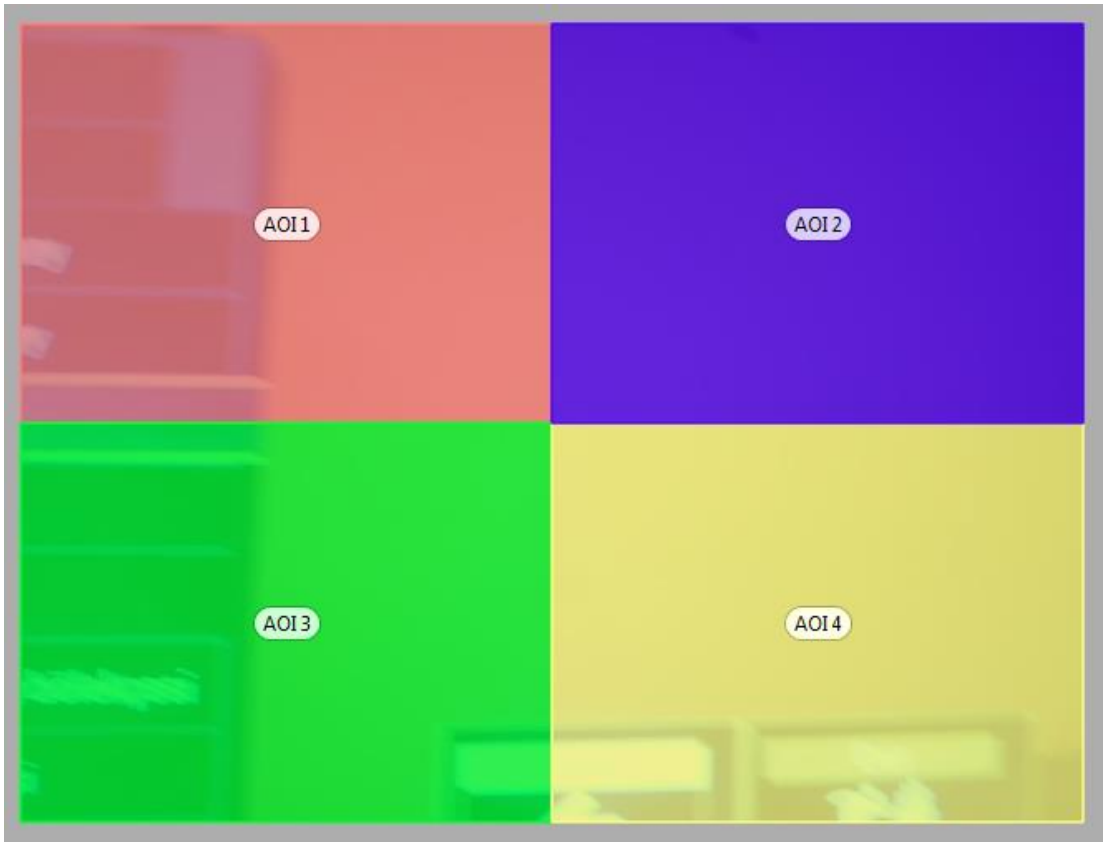


Figure 14 - Division of AOIs

As the second step of the data analysis, the interview data were analyzed for Test 1, Test 2 and Test 3. Firstly, interview records were transcribed into text. Then, retrospective review data were separated from the interview data and grouped according to time intervals. Retrospective review data were used to support the results came from the first step of the data analysis. After separating retrospective review data, the coding was done by the researcher. Two experts, a faculty member and a PhD student, reviewed the codes that the researcher derived from the transcriptions. The aim was to select appropriate keywords to code the data. After that, corrections was done by the researcher according to feedback of experts. After finalizing the coding of the interviews, the quotations of users with main codes and sub-themes were described in the results chapter.

CHAPTER IV

RESULTS

All results obtained from this study are presented under this chapter. The results are interpreted under four main headings, namely “Results of Test 1”, “Results of Test 2”, “Comparison of Test 1 and Test 2” and “Results of Interviews”.

During the interpretation of results, the abbreviations in the Table 6 are used.

Table 6 - Abbreviations for Result

EU 1	Expert User 1
NEU 1	Non-Expert User 1
NEU 2	Non-Expert User 2
NEU 3	Non-Expert User 3
AOI	Area of Interest
TFD	Total Fixation Duration (sec)
TFD/TCTPI	Total Fixation Duration (sec) / Task Completion Time per Interval (sec)
FC	Fixation Count
FC/TCTPI	Fixation Count / Task Completion Time per Interval (sec)
TC	Transition Counts
TC/TCTPI	Transition Counts / Task Completion Time per Interval (sec)
C	Counts
C/TCTPI	Counts / Task Completion Time per Interval (sec)
D	Durations (sec)
D/TCTPI	Durations (sec) / Task Completion Time per Interval (sec)

4.1 RESULTS OF TEST 1

The results of Test 1 are presented under 10 time intervals as it is seen in the Table 7 for Expert User 1 (EU 1) and Non-Expert User 1 (NEU 1). There is a subheading for each time interval for Test 1. The gaze plot data, eye tracking data and retrospective review results are presented for the each time interval.

Table 7 - Test 1: Time Intervals Distribution

	EU 1		**NEU 1**	
	Start Time (sec)	**Finish Time (sec)**	**Start Time (sec)**	**Finish Time (sec)**
Total Task Duration (0%-100%)	0.000	328.550	0.000	608.850
Time Interval 1 (0%-10%)	0.000	32.855	0.000	60.885
Time Interval 2 (10%-20%)	32.855	65.710	60.885	121.770
Time Interval 3 (20%-30%)	65.710	98.565	121.770	182.655
Time Interval 4 (30%-40%)	98.565	131.420	182.655	243.540
Time Interval 5 (40%-50%)	131.420	164.275	243.540	304.425
Time Interval 6 (50%-60%)	164.275	197.130	304.425	365.310
Time Interval 7 (60%-70%)	197.130	229.985	365.310	426.195
Time Interval 8 (70%-80%)	229.985	262.840	426.195	487.080
Time Interval 9 (80%-90%)	262.840	295.695	487.080	547.965
Time Interval 10 (90%-100%)	295.695	328.550	547.965	608.850

Each time interval for Expert User 1 (EU 1) consists of 32.855 seconds and the total task duration of the EU 1 is 328.550 seconds. Each time interval for Non-Expert User 1 (NEU 1) consists of 60.885 seconds and the total task duration of the NEU 1 is 608.850 seconds. As it is seen from this result, NEU 1 spent significant amount of time on task.

4.1.1 TIME INTERVAL 1

Time interval 1 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 1. Figure 15 shows the gaze plots of EU 1 and NEU 1 during Time Interval 1.

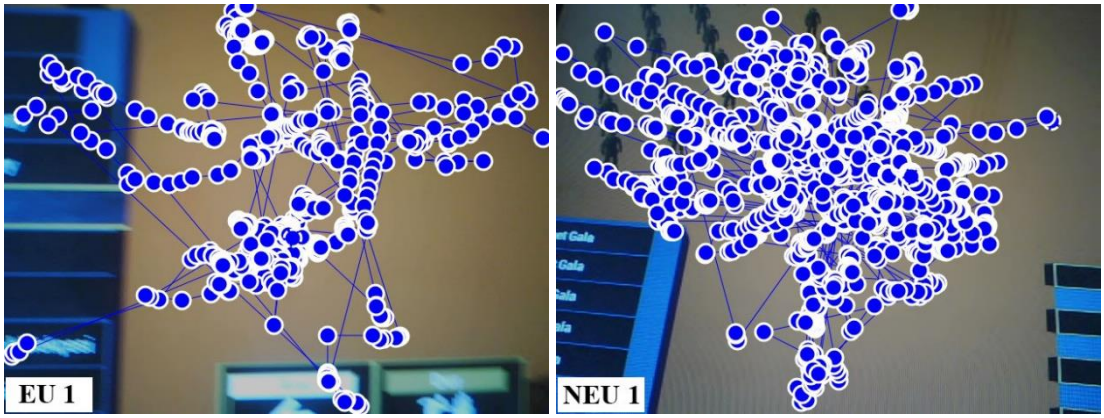


Figure 15 - Test 1: Time Interval 1 - Gaze Plots

Table 8 shows fixation durations and fixation counts of the EU 1 and NEU 1 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 8 - Test 1: Time Interval 1 - Fixation Durations and Fixation Counts

Time Interval 1 (0%-10%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	5.24	7.30	5.53	6.03	24.10
	NEU 1	18.50	14.89	6.70	9.47	49.56
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.159**	**0.222**	**0.168**	**0.184**	0.734
	NEU 1	**0.304**	**0.245**	0.110	0.156	0.814
Fixation Count	**EU 1**	158	219	166	181	724
	NEU 1	555	447	201	284	1487
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**4.809**	**6.666**	**5.053**	**5.509**	22.036
	NEU 1	**9.116**	**7.342**	3.301	4.665	24.423

As it is seen from the Figure 15, the gaze plots of the EU 1 are spread around the screen, while the gaze plots of the NEU 1 are mostly on the upper center of the screen. Parallel to the Figure 15, it is seen in the Table 8 that TFD/TCTPI data and FC/TCTPI data of the EU 1 are almost equal for each AOIs. However, TFD/TCTPI data and FC/TCTPI data for NEU 1 on AOI 1 and AOI 2 are higher than the data on AOI 3 and AOI 4. This indicates that EU 1 was preparing for the task by checking menus and objects on the screen, while NEU 1 was trying to adapt the software by looking mostly at the objects and the area that are placed on the upper center of the screen.

During the retrospective review, NEU 1 also supported this by saying: “Firstly, I came and checked what there is in the guardhouse. I am looking from wide angle. I am looking at my vehicles and my units. I am matching the menu items with the objects on the real interface in my mind like which unit is which one, which vehicle is which one.”

> *“Geldim karakolda neler var bir onlara baktım öncelikle. Geniş açıdan bakıyorum. Araçlarıma birliklerime bakıyorum. Hangi birlik hangisi, hangi araç hangisi gibi menüdeki kısımlarla oyunun gerçek arayüzde görünen kısımlara eşleştiriyorum kafamda.” [NEU 1]*

Table 9 shows counts and durations of EU 1 and NEU 1 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 9 - Test 1: Time Interval 1 - Tracked Area and Command

Time Interval 1 (0%-10%)		**Tracked Area**			**Command**
		Inside Menu	**Outside Menu**	**Objects**	**Move Command**
Transition Counts	**EU 1**	7	8	9	0
	NEU 1	11	12	13	0
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.213	0.243	**0.274**	0.000
	NEU 1	0.181	0.197	**0.214**	0.000
Durations (sec)	**EU 1**	14.178	18.685	6.696	0.000
	NEU 1	16.172	44.589	11.277	0.000
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.432**	**0.569**	**0.204**	0.000
	NEU 1	**0.266**	**0.732**	**0.185**	0.000

Table 9 shows that TC/TCTPI data and D/TCTPI data for Objects are almost same for both of users. On the other hand, the D/TCTPI data difference between Inside Menu and Outside Menu for NEU 1 is higher than the difference for EU 1. It indicates that while EU 1 was looking at the menu area and out of menu area with almost equal durations, NEU 1 was concentrating on out of menu area more than the menu area.

Table 10 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 10 - Test 1: Time Interval 1 - Gestures

Time Interval 1 (0%-10%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	12	1	0	0	1	1
	NEU 1	16	3	0	0	1	6
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.365**	**0.030**	0.000	0.000	0.030	**0.030**
	NEU 1	**0.263**	**0.049**	0.000	0.000	0.016	**0.099**
Durations (sec)	**EU 1**	-	1.133	0.000	0.000	0.515	0.412
	NEU 1	-	8.524	0.000	0.000	0.790	14.573
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.034**	0.000	0.000	0.016	**0.013**
	NEU 1	-	**0.140**	0.000	0.000	0.013	**0.239**

As it is seen in the Table 10, C/TCTPI data for Tap gesture for EU 1 is higher than for NEU 1, but C/TCTPI data and D/TCTPI data for Zoom Out gesture and Drag gesture for EU 1 is smaller than for NEU 1. It indicates that EU 1 explored the objects and the area mostly by tapping from menu while NEU 1 explored the objects and area mostly by using Zoom Out gesture and Drag gesture.

4.1.2 TIME INTERVAL 2

Time interval 2 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 1. Figure 16 shows the gaze plots of EU 1 and NEU 1 during Time Interval 2.

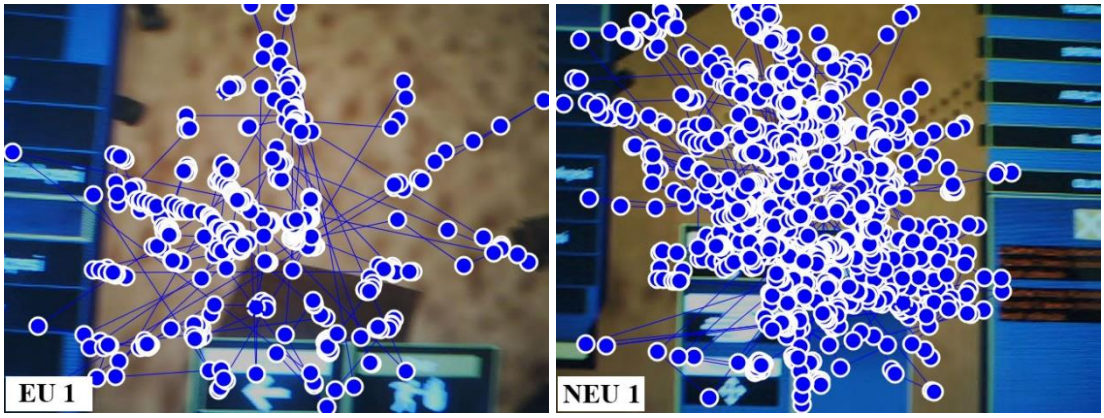


Figure 16 - Test 1: Time Interval 2 - Gaze Plots

Table 11 shows fixation durations and fixation counts of the EU 1 and NEU 1 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 11 - Test 1: Time Interval 2 - Fixation Durations and Fixation Counts

Time Interval 2 (10%-20%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	3.10	2.87	6.17	4.37	16.51
	NEU 1	19.10	6.94	14.53	10.28	50.85
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	0.094	0.087	**0.188**	**0.133**	0.503
	NEU 1	**0.314**	0.114	**0.239**	0.169	0.835
Fixation Count	**EU 1**	93	86	185	131	495
	NEU 1	573	209	436	309	1527
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	2.831	2.618	**5.631**	**3.987**	15.066
	NEU 1	**9.411**	3.433	**7.161**	5.075	25.080

As it is seen from the Figure 16, the gaze plots of the EU 1 are spread around the screen, while the gaze plots of the NEU 1 are mostly on the center of the screen. It is seen in the Table 11 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 3 and AOI 4 are higher than for AOI 1 and AOI 2. However, TFD/TCTPI data and FC/TCTPI data for NEU 1 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on left side of the screen which includes left menu, while NEU 1 was mostly working on out of menu which includes objects on the area.

During the retrospective review, EU 1 supported this by saying: "Here, I was looking around menus."

> *"İşte menüler arasında gezinti yapıyorum." [EU 1]*

NEU 1 also supported this by saying: "I went to the case area for investigating this area. I observed that there is a person who is smuggler or opponent. I saw that he is running away. Again, I turned back to my guardhouse."

> *"Olay yerini incelemek için olayın olduğu yere gittim. Orada kaçakçı veya işte karşı taraf olduğunu fark ettiğim bir insanı gözlemledim. Kaçtığını gördüm. Tekrar kendi karakoluma döndüm." [NEU 1]*

Table 12 shows counts and durations of EU 1 and NEU 1 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 12 - Test 1: Time Interval 2 - Tracked Area and Command

Time Interval 2 (10%-20%)		Tracked Area			Command
		Inside Menu	Outside Menu	Objects	Move Command
Transition Counts	**EU 1**	6	5	6	0
	NEU 1	13	13	11	0
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.183	0.152	**0.183**	0.000
	NEU 1	0.214	0.214	**0.181**	0.000
Durations (sec)	**EU 1**	16.094	16.756	3.844	0.000
	NEU 1	27.594	33.288	5.960	0.000
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.490**	**0.510**	**0.117**	0.000
	NEU 1	**0.453**	**0.547**	**0.098**	0.000

Table 12 shows that TC/TCTPI data and D/TCTPI data for Objects are almost same for both of users. On the other hand, the D/TCTPI data difference between Inside Menu and Outside Menu for NEU 1 is a little bit higher than the difference for EU 1. It indicates that while EU 1 was looking at the menu area and out of menu area with almost equal durations, NEU 1 was concentrating on out of menu area a little bit more than the menu area.

Table 13 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 13 - Test 1: Time Interval 2 - Gestures

Time Interval 2 (10%-20%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	10	1	0	0	0	1
	NEU 1	7	3	0	0	0	3
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.304**	**0.030**	0.000	0.000	0.000	**0.030**
	NEU 1	**0.115**	**0.049**	0.000	0.000	0.000	**0.049**
Durations (sec)	**EU 1**	-	1.064	0.000	0.000	0.000	0.309
	NEU 1	-	7.724	0.000	0.000	0.000	3.727
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.032**	0.000	0.000	0.000	**0.009**
	NEU 1	-	**0.127**	0.000	0.000	0.000	**0.061**

As it is seen in the Table 13, C/TCTPI data for Tap gesture for EU 1 is higher than for NEU 1, but C/TCTPI data and D/TCTPI data for Zoom Out gesture and Drag gesture for EU 1 is smaller than for NEU 1. It indicates that EU 1 explored the objects and the area mostly by tapping from menu while NEU 1 explored the objects and area mostly by using Zoom Out gesture and Drag gesture.

4.1.3 TIME INTERVAL 3

Time interval 3 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 1. Figure 17 shows the gaze plots of EU 1 and NEU 1 during Time Interval 3.

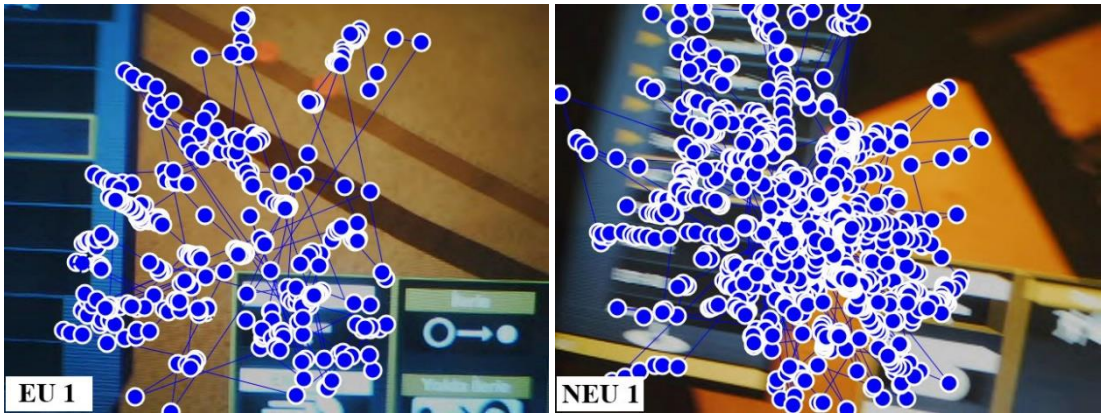


Figure 17 - Test 1: Time Interval 3 - Gaze Plots

Table 14 shows fixation durations and fixation counts of the EU 1 and NEU 1 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 14 - Test 1: Time Interval 3 - Fixation Durations and Fixation Counts

Time Interval 3 (20%-30%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	3.00	1.57	5.93	2.60	13.10
	NEU 1	13.13	5.13	18.00	13.15	49.41
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.091**	0.048	**0.180**	**0.079**	0.399
	NEU 1	**0.216**	0.084	**0.296**	**0.216**	0.812
Fixation Count	**EU 1**	90	47	178	78	393
	NEU 1	394	154	540	395	1483
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**2.739**	1.431	**5.418**	**2.374**	11.962
	NEU 1	**6.471**	2.529	**8.869**	**6.488**	24.357

As it is seen from the Figure 17, the gaze plots of the EU 1 and NEU 1 are mostly on the center and left side of the screen. It is seen in the Table 14 that TFD/TCTPI data and FC/TCTPI data of the EU 1 and NEU 1 for AOI 1, AOI 3 and AOI 4 are higher than for AOI 2. Both of EU 1 and NEU 1 have similar pattern. This indicates that EU 1 and NEU 1 were mostly working on the screen except from right upper side which includes left menu, middle menu and most of working area with objects.

Table 15 shows counts and durations of EU 1 and NEU 1 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 15 - Test 1: Time Interval 3 - Tracked Area and Command

Time Interval 2 (20%-30%)		**Tracked Area**			**Command**
		Inside Menu	**Outside Menu**	**Objects**	**Move Command**
Transition Counts	**EU 1**	5	5	0	3
	NEU 1	13	13	6	4
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.152	0.152	**0.000**	0.091
	NEU 1	0.214	0.214	**0.099**	0.066
Durations (sec)	**EU 1**	21.094	11.768	0.000	1.958
	NEU 1	32.778	28.117	0.893	3.603
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.642**	**0.358**	**0.000**	0.060
	NEU 1	**0.538**	**0.462**	**0.015**	0.059

Table 15 shows that TC/TCTPI data and D/TCTPI data of NEU 1 for Objects exist as very small number, while such data of EU 1 does not exist. On the other hand, the D/TCTPI data difference between Inside Menu and Outside Menu for EU 1 is a little bit higher than the difference for NEU 1. It indicates that while EU 1 was looking at the menu area more than the out of menu area, NEU 1 was concentrating on menu area and out of menu area with almost equal durations.

During the retrospective review, EU 1 supported this by saying: "Now, I am giving command. I selected necessary information for this command, and specified the target like move to there. Of course, I selected all of these via interface again."

> *"Şu an görev veriyorum. Görev için gerekli girdileri seçtim ve hedef verdim şuraya hareket et gibisinden. Tabi bunların hepsini yine arayüz üzerinden yapıyorum seçimlerimi." [EU 1]*

Table 16 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 16 - Test 1: Time Interval 3 - Gestures

Time Interval 3 (20%-30%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	11	0	0	0	0	6
	NEU 1	21	2	0	0	0	5
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.335**	**0.000**	0.000	0.000	0.000	**0.183**
	NEU 1	**0.345**	**0.033**	0.000	0.000	0.000	**0.082**
Durations (sec)	**EU 1**	-	0.000	0.000	0.000	0.000	5.426
	NEU 1	-	4.326	0.000	0.000	0.000	4.427
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.000**	0.000	0.000	0.000	**0.165**
	NEU 1	-	**0.071**	0.000	0.000	0.000	**0.073**

As it is seen in the Table 16, C/TCTPI data for Tap gesture is almost same for EU 1 and NEU 1. C/TCTPI data and D/TCTPI data for Zoom Out gesture exist only for NEU 1. C/TCTPI data and D/TCTPI data for Drag gesture for EU 1 is higher than for NEU 1. It indicates that while EU 1 was trying to understand and explore the event and to give an order to send a vehicle to the event area, NEU 1 is checking the event and giving command to send a vehicle to the event area.

During the retrospective review, EU 1 supported: "Now, for example, an event was came. I am trying to focus camera there. For example, I am moving the camera now. I am dragging."

> *"Şu an mesela bir olay gelmiş. Onunla kamerayı oraya odaklamaya çalışıyorum. Şu an kamerayı hareket ettiriyorum mesela. Sürüklüyorum. Şu an görev veriyorum." [EU 1]*

NEU 1 also supported: "I put the selected unit on a vehicle. I move the vehicle to the event area. I am moving the other vehicle that I put the other soldiers on to the event area."

> *"Seçtiğim bir bölüğü bir araca bindiriyorum. Aracı olay yerine doğru hareket ettirdim. Diğer askerleri bindirdiğim diğer aracı da olay yerine hareket ettiriyorum." [NEU 1]*

4.1.4 TIME INTERVAL 4

Time interval 4 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 1. Figure 18 shows the gaze plots of EU 1 and NEU 1 during Time Interval 4.

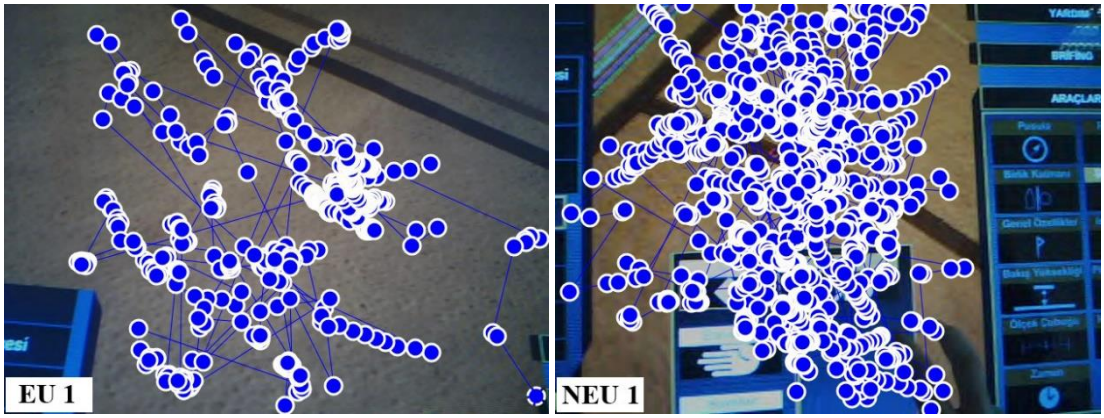


Figure 18 - Test 1: Time Interval 4 - Gaze Plots

Table 17 shows fixation durations and fixation counts of the EU 1 and NEU 1 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 17 - Test 1: Time Interval 4 - Fixation Durations and Fixation Counts

Time Interval 4 (30%-40%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	2.03	8.03	5.20	4.43	19.69
	NEU 1	25.77	7.80	12.07	5.07	50.71
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	0.062	**0.244**	**0.158**	**0.135**	0.599
	NEU 1	**0.423**	0.128	**0.198**	0.083	0.833
Fixation Count	**EU 1**	61	241	157	133	592
	NEU 1	773	234	362	152	1521
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	1.857	**7.335**	**4.779**	**4.048**	18.019
	NEU 1	**12.696**	3.843	**5.946**	2.497	24.982

As it is seen from the Figure 18, the gaze plots of the EU 1 and NEU 1 are mostly on the center and left side of the screen. It is seen in the Table 17 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 2, AOI 3 and AOI 4 are higher than for AOI 1. However, TFD/TCTPI data and FC/TCTPI data for NEU 1 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on right side of the screen which includes right menu and left bottom side of the screen which includes a part of left menu, while NEU 1 was mostly working on left side of the screen which includes left menu.

Table 18 shows counts and durations of EU 1 and NEU 1 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 18 - Test 1: Time Interval 4 - Tracked Area and Command

Time Interval 4 (30%-40%)		**Tracked Area**			**Command**
		Inside Menu	**Outside Menu**	**Objects**	**Move Command**
Transition Counts	**EU 1**	2	3	0	1
	NEU 1	14	15	0	2
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.061	0.091	**0.000**	0.030
	NEU 1	0.230	0.246	**0.000**	0.033
Durations (sec)	**EU 1**	18.225	14.639	0.000	0.618
	NEU 1	17.752	43.103	0.000	1.100
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.555**	**0.446**	**0.000**	0.019
	NEU 1	**0.292**	**0.708**	**0,000**	0,018

Table 18 shows that TC/TCTPI data and D/TCTPI data of EU 1 and NEU 1 for Objects do not exist. On the other hand, the D/TCTPI data difference between Inside Menu and Outside Menu for EU 1 is much smaller than the difference for NEU 1. It indicates that while EU 1 was looking at both the menu area and the out of menu area with almost same durations, NEU 1 was concentrating on out of menu area more than menu area.

During the retrospective review, NEU 1 supported this by saying only: "I am checking the positions of my vehicles to see whether they arrived or where they are. I enabled the border view and shape layer for seeing other information. Still, I am waiting for my vehicle."

> *"Araçlarımın durumunu kontrol ediyorum, gelmişler mi diye ne durumdalar diye. Sınır çizgilerini ve diğer bilgileri görebilmek için şekil katmanını açtım. Hala aracımı bekliyorum." [NEU 1]*

Table 19 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 19 - Test 1: Time Interval 4 - Gestures

Time Interval 4 (30%-40%)		**Gestures**					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	16	1	1	0	0	4
	NEU 1	7	2	0	0	0	8
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.487**	**0.030**	**0.030**	0.000	0.000	**0.122**
	NEU 1	**0.115**	**0.033**	**0.000**	0.000	0.000	**0.131**
Durations (sec)	**EU 1**	-	0.013	1.957	0.000	0.000	2.025
	NEU 1	-	6.730	0.000	0.000	0.000	12.019
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.000**	**0.060**	0.000	0.000	**0.062**
	NEU 1	-	**0.111**	**0.000**	0.000	0.000	**0.197**

As it is seen in the Table 19, C/TCTPI data for Tap gesture for EU 1 is higher than for NEU 1. C/TCTPI data and D/TCTPI data for Zoom Out gesture and Drag gesture are almost same for both EU 1 and NEU 1. It indicates that both EU 1 and NEU 1 were moving around the area and making selections between menus by tapping, but EU 1 was tapping more than NEU 1.

During the retrospective review, EU 1 supported this by saying: "Now, I am making selections between menus again. Now, I am trying to select target here again."

> *"Şu an menüler arasında yine seçim yapıyorum. Şu an burada yine hedef seçmeye çalıştım." [EU 1]*

4.1.5 TIME INTERVAL 5

Time interval 5 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 1. Figure 19 shows the gaze plots of EU 1 and NEU 1 during Time Interval 5.

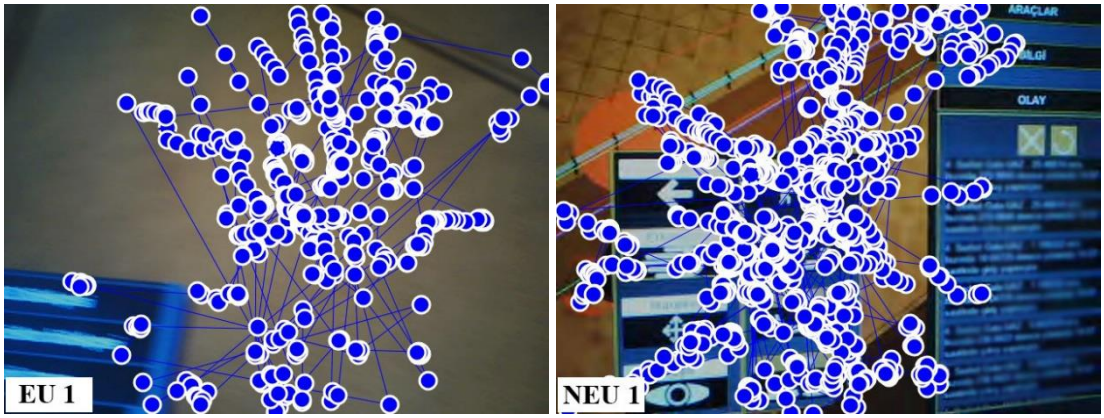


Figure 19 - Test 1: Time Interval 5 - Gaze Plots

Table 20 shows fixation durations and fixation counts of the EU 1 and NEU 1 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 20 - Test 1: Time Interval 5 - Fixation Durations and Fixation Counts

Time Interval 5 (40%-50%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	2.23	8.81	3.03	6.37	20.44
	NEU 1	12.72	9.60	17.80	7.70	47.82
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	0.068	**0.268**	0.092	**0.194**	0.622
	NEU 1	**0.209**	0.158	**0.292**	0.126	0.785
Fixation Count	**EU 1**	67	265	91	191	614
	NEU 1	382	288	535	231	1436
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	2.039	**8.066**	2.770	**5.813**	18.688
	NEU 1	**6.274**	4.730	**8.787**	3.794	23.585

As it is seen from the Figure 19, the gaze plots of the EU 1 are mostly on the center of the screen while the gaze plots of the NEU 1 are mostly on the center and left side of the screen. It is seen in the Table 20 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 2 and AOI 4 are higher than for AOI 1 and AOI 3. However, TFD/TCTPI data and FC/TCTPI data for NEU 1 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on right side of the screen which includes right menu, while NEU 1 was mostly working on left side of the screen which includes left menu.

Table 21 shows counts and durations of EU 1 and NEU 1 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 21 - Test 1: Time Interval 5 - Tracked Area and Command

Time Interval 5 (40%-50%)		**Tracked Area**			**Command**
		Inside Menu	**Outside Menu**	**Objects**	**Move Command**
Transition Counts	**EU 1**	5	5	4	1
	NEU 1	14	14	8	1
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.152	0.152	**0.122**	0.030
	NEU 1	0.230	0.230	**0.131**	0.016
Durations (sec)	**EU 1**	6.970	25.884	2.507	0.824
	NEU 1	28.459	32.428	8.479	0.721
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.212**	**0.788**	**0.076**	0.025
	NEU 1	**0.467**	**0.533**	**0.139**	0.012

Table 21 shows that TC/TCTPI data and D/TCTPI data for Objects on EU 1 are smaller than on NEU 1. On the other hand, the D/TCTPI data difference between Inside Menu and Outside Menu for EU 1 is higher than the difference for NEU 1. It indicates that while EU 1 was looking at out of menu area more than menu area, NEU 1 was concentrating on both the menu area and the out of menu area with almost same durations.

Table 22 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 22 - Test 1: Time Interval 5 - Gestures

Time Interval 5 (40%-50%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	6	2	2	0	0	5
	NEU 1	20	2	0	0	0	4
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.183**	**0.061**	**0.061**	0.000	0.000	**0.152**
	NEU 1	**0.328**	**0.033**	**0.000**	0.000	0.000	**0.066**
Durations (sec)	**EU 1**	-	4.896	3.226	0.000	0.000	4.377
	NEU 1	-	6.008	0.000	0.000	0.000	4.086
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.149**	**0.098**	0.000	0.000	**0.133**
	NEU 1	-	**0.099**	**0.000**	0.000	0.000	**0.067**

As it is seen in the Table 22, C/TCTPI data for Tap gesture for EU 1 is smaller than for NEU 1. C/TCTPI data and D/TCTPI data for Zoom Out gesture and Drag gesture on EU 1 is higher than on NEU 1. Also, C/TCTPI data and D/TCTPI data for Zoom In gesture for EU 1 exist, while such data for NEU 1 do not exist. It indicates that EU 1 was moving around the area and working on objects, while NEU 1 was moving around the area and making selections between menus by using Tap gesture more.

During the retrospective review, EU 1 supported this by saying: "I am trying to select appropriate target for the mission which I gave."

"Verdiğim göreve uygun hedefi seçmeye çalışıyorum." [EU 1]

4.1.6 TIME INTERVAL 6

Time interval 6 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 1. Figure 20 shows the gaze plots of EU 1 and NEU 1 during Time Interval 6.

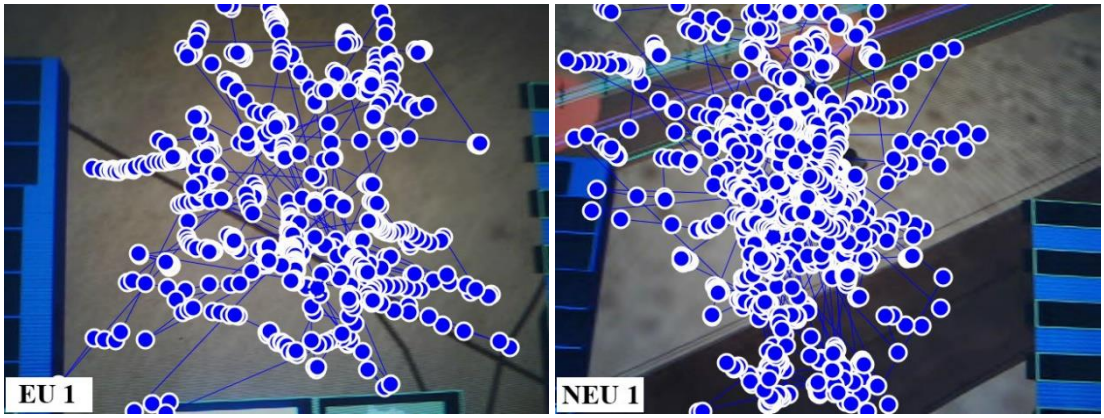


Figure 20 - Test 1: Time Interval 6 - Gaze Plots

Table 23 shows fixation durations and fixation counts of the EU 1 and NEU 1 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 23 - Test 1: Time Interval 6 - Fixation Durations and Fixation Counts

Time Interval 6 (50%-60%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	5.37	5.75	3.03	9.17	23.32
	NEU 1	23.05	6.73	13.71	7.00	50.49
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.163**	**0.175**	0.092	**0.279**	0.710
	NEU 1	**0.379**	0.111	**0.225**	0.115	0.829
Fixation Count	**EU 1**	161	173	91	276	701
	NEU 1	692	202	412	210	1516
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**4.900**	**5.266**	2.770	**8.401**	21.336
	NEU 1	**11.366**	3.318	**6.767**	3.449	24.899

As it is seen from the Figure 20, the gaze plots of the EU 1 are mostly on the center of the screen, while the gaze plots of the NEU 1 are mostly on the center and upper left side of the screen. It is seen in the Table 23 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1, AOI 2 and AOI 4 are higher than for AOI 3. However, TFD/TCTPI data and FC/TCTPI data for NEU 1 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on right side of the screen which includes right menu and out of menu area which includes objects, while NEU 1 was mostly working on left side of the screen which includes left menu.

Table 24 shows counts and durations of EU 1 and NEU 1 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 24 - Test 1: Time Interval 6 - Tracked Area and Command

Time Interval 6 (50%-60%)		**Tracked Area**			**Command**
		Inside Menu	**Outside Menu**	**Objects**	**Move Command**
Transition Counts	**EU 1**	2	1	0	1
	NEU 1	13	13	11	2
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.061	0.030	**0.000**	0.030
	NEU 1	0.214	0.214	**0.181**	0.033
Durations (sec)	**EU 1**	10.046	22.885	0.000	0.858
	NEU 1	21.462	39.428	9.476	1.648
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.306**	**0.697**	**0.000**	0.026
	NEU 1	**0.353**	**0.648**	**0.156**	0.027

Table 24 shows that TC/TCTPI data and D/TCTPI data of EU 1 for Objects do not exist, while such data of NEU 1 for objects exist significantly. On the other hand, the D/TCTPI data of EU 1 and NEU 1 for Outside Menu is higher than the data for Inside Menu. It indicates that both EU 1 and NEU 1 were looking at the out of menu area more than menu area in durations.

During the retrospective review, EU 1 supported this by saying: "Now, I gave a command again and select an appropriate target for this command."

"Hani yine görev verip işte göreve uygun hedef seçtim." [EU 1]

Also, NEU 1 supported this by saying: "I took of my soldiers from the other vehicle too. I selected my units for searching for smuggler. Then, I started to move my unit for searching the smuggler."

"Diğer araçtaki askerlerimi de indirdim. Kaçakçıyı arayacağım birliklerimi seçtim. Daha sonra ilerletmeye başladım kaçakçıyı aramaları için." [NEU 1]

Table 25 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 25 - Test 1: Time Interval 6 - Gestures

Time Interval 6 (50%-60%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	6	3	1	0	0	5
	NEU 1	15	1	1	0	0	8
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.183**	**0.091**	**0.030**	0.000	0.000	**0.152**
	NEU 1	**0.246**	**0.016**	**0.016**	0.000	0.000	**0.131**
Durations (sec)	**EU 1**	-	3.261	1.683	0.000	0.000	3.245
	NEU 1	-	0.996	1.820	0.000	0.000	12.751
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.099**	**0.051**	0.000	0.000	**0.099**
	NEU 1	-	**0.016**	**0.030**	0.000	0.000	**0.209**

As it is seen in the Table 25, C/TCTPI data for Tap gesture for EU 1 is smaller than for NEU 1. C/TCTPI data and D/TCTPI data for Zoom Out gesture, Zoom In gesture and Drag gesture for EU 1 is higher than for NEU 1. It indicates that EU 1 was moving around the area more than NEU 1 and making selections less than NEU 1.

4.1.7 TIME INTERVAL 7

Time interval 7 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 1. Figure 21 shows the gaze plots of EU 1 and NEU 1 during Time Interval 7.

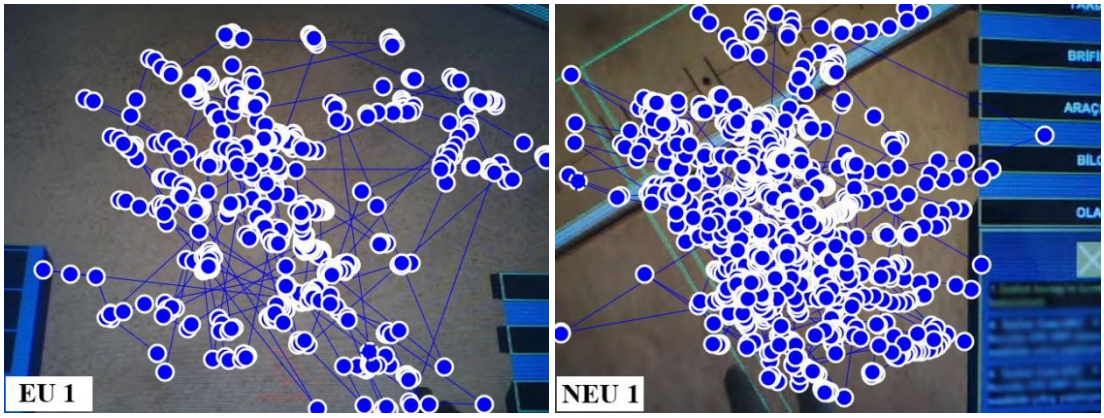


Figure 21 - Test 1: Time Interval 7 - Gaze Plots

Table 26 shows fixation durations and fixation counts of the EU 1 and NEU 1 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 26 - Test 1: Time Interval 7 - Fixation Durations and Fixation Counts

Time Interval 7 (60%-70%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	7.53	5.60	3.67	8.08	24.88
	NEU 1	18.73	2.53	22.23	7.07	50.56
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.229**	0.170	0.112	**0.246**	0.757
	NEU 1	**0.308**	0.042	**0.365**	0.116	0.830
Fixation Count	**EU 1**	226	168	110	243	747
	NEU 1	562	76	667	212	1517
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**6.879**	5.113	3.348	**7.396**	22.736
	NEU 1	**9.231**	1.248	**10.955**	3.482	24.916

As it is seen from the Figure 21, the gaze plots of the EU 1 and NEU 1 are mostly on the center of the screen. It is seen in the Table 26 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1 and AOI 4 are higher than for AOI 2 and AOI 3. However, TFD/TCTPI data and FC/TCTPI data for NEU 1 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on right side of the screen which includes right menu and left upper side of the screen which includes objects, while NEU 1 was mostly working on left side of the screen which includes left menu.

Table 27 shows counts and durations of EU 1 and NEU 1 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 27 - Test 1: Time Interval 7 - Tracked Area and Command

Time Interval 7 (60%-70%)		**Tracked Area**			**Command**
		Inside Menu	**Outside Menu**	**Objects**	**Move Command**
Transition Counts	**EU 1**	3	4	0	0
	NEU 1	16	17	0	1
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.091	0.122	**0.000**	0.000
	NEU 1	0.263	0.279	**0.000**	0.016
Durations (sec)	**EU 1**	6.468	26.388	0.000	0.000
	NEU 1	20.120	40.773	0.000	1.168
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.197**	**0.803**	**0.000**	0.000
	NEU 1	**0.330**	**0.670**	**0.000**	0.019

Table 27 shows that TC/TCTPI data and D/TCTPI data of EU 1 and NEU 1 for Objects do not exist. On the other hand, the D/TCTPI data of EU 1 and NEU 1 for Outside Menu is higher than the data for Inside Menu. It indicates that both EU 1 and NEU 1 were looking at the out of menu area more than menu area in durations.

During the retrospective review, NEU 1 supported this by saying: "In order not to lose much time, I put on my soldiers to the vehicle as soon as possible. I sent my vehicle to the area that the smuggler is probably at as soon as possible."

> *"Vakit kaybetmemek için bir an önce tekrar askerlerimi bindirdim. Aracımı kaçakçının muhtemel bulunduğu yere yönlendirdim bir an önce." [NEU 1]*

Table 28 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 28 - Test 1: Time Interval 7 - Gestures

Time Interval 7 (60%-70%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	5	0	1	0	0	1
	NEU 1	12	1	0	1	0	7
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.152**	**0.000**	**0.030**	**0.000**	0.000	**0.030**
	NEU 1	**0.197**	**0.016**	**0.000**	**0.016**	0.000	**0.115**
Durations (sec)	**EU 1**	-	0.000	0.584	0.000	0.000	1.030
	NEU 1	-	1.991	0.000	0.996	0.000	6.306
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.000**	**0.018**	**0.000**	0.000	**0.031**
	NEU 1	-	**0.033**	**0.000**	**0.016**	0.000	**0.104**

As it is seen in the Table 28, C/TCTPI data for Tap gesture for EU 1 is smaller than for NEU 1. C/TCTPI data and D/TCTPI data for Zoom Out gesture and Select gesture on EU 1 do not exist, while such data on NEU 1 exist. C/TCTPI data and D/TCTPI data for Zoom In gesture on EU 1 exist, while such data on NEU 1 do not exist. C/TCTPI data and D/TCTPI data for Drag gesture on EU 1 are much smaller than on NEU 1. It indicates that EU 1 was more stable than NEU 1.

During the retrospective review, EU 1 supported this by saying: “Now, I am moving between side menus. I am looking at menus.”

“Şu an yan menüler arasında gezinti yapıyorum. Menülere bakıyorum.” [EU 1]

4.1.8 TIME INTERVAL 8

Time interval 8 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 1. Figure 22 shows the gaze plots of EU 1 and NEU 1 during Time Interval 8.

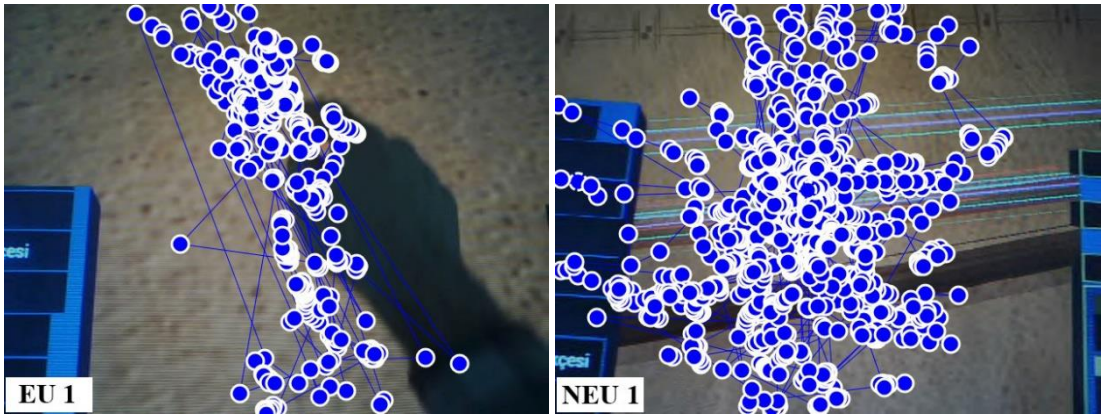


Figure 22 - Test 1: Time Interval 8 - Gaze Plots

Table 29 shows fixation durations and fixation counts of the EU 1 and NEU 1 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 29 - Test 1: Time Interval 8 - Fixation Durations and Fixation Counts

Time Interval 8 (70%-80%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	9.52	6.00	0.77	4.58	20.87
	NEU 1	16.87	4.57	15.93	6.50	43.87
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.290**	**0.183**	0.023	**0.139**	0.635
	NEU 1	**0.277**	0.075	**0.262**	0.107	0.721
Fixation Count	**EU 1**	286	180	23	138	627
	NEU 1	507	137	478	195	1317
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**8.705**	**5.479**	0.700	**4.200**	19.084
	NEU 1	**8.327**	2.250	**7.851**	3.203	21.631

As it is seen from the Figure 22, the gaze plots of the EU 1 are mostly on the upper center of the screen, while the gaze plots of the NEU 1 are mostly on the center and left side of the screen. It is seen in the Table 29 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1, AOI 2 and AOI 4 are higher than for AOI 3. However, TFD/TCTPI data and FC/TCTPI data for NEU 1 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on upper of the screen which includes objects and right bottom side of the screen which includes a part of right menu, while NEU 1 was mostly working on left side of the screen which includes left menu.

Table 30 shows counts and durations of EU 1 and NEU 1 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 30 - Test 1: Time Interval 8 - Tracked Area and Command

Time Interval 8 (70%-80%)		**Tracked Area**			**Command**
		Inside Menu	**Outside Menu**	**Objects**	**Move Command**
Transition Counts	**EU 1**	4	3	0	1
	NEU 1	12	13	4	4
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.122	0.091	**0.000**	0.030
	NEU 1	0.197	0.214	**0.066**	0.066
Durations (sec)	**EU 1**	7.093	25.729	0.000	0.652
	NEU 1	15.724	45.160	2.369	3.262
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.216**	**0.783**	**0.000**	0.020
	NEU 1	**0.258**	**0.742**	**0.039**	0.054

Table 30 shows that TC/TCTPI data and D/TCTPI data of EU 1 for Objects do not exist, while such data of NEU 1 for Objects exist in small duration. On the other hand, the D/TCTPI data of EU 1 and NEU 1 for Outside Menu is higher than the data for Inside Menu. It indicates that both EU 1 and NEU 1 were looking at the out of menu area more than menu area in durations.

During the retrospective review, EU 1 supported this by saying: "I am trying to find my target which I want to follow in this area. I set the camera position too in order to see both my vehicle and target at the same time."

> *"Bu alanda takip etmek istediğim hedefimi bulmaya çalışıyorum. Hem aracımı hem de hedefi aynı anda görmek için kamera pozisyonumu da ayarladım." [EU 1]*

Table 31 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 31 - Test 1: Time Interval 8 - Gestures

Time Interval 8 (70%-80%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	3	0	3	2	0	3
	NEU 1	14	5	0	0	1	6
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.091**	**0.000**	**0.091**	**0.061**	**0.000**	**0.091**
	NEU 1	**0.230**	**0.082**	**0.000**	**0.000**	**0.016**	**0.099**
Durations (sec)	**EU 1**	-	0.000	3.398	0.618	0.000	2.987
	NEU 1	-	8.584	0.000	0.000	1.854	6.661
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.000**	**0.103**	**0.019**	**0.000**	**0.091**
	NEU 1	-	**0.141**	**0.000**	**0.000**	**0.030**	**0.109**

As it is seen in the Table 31, C/TCTPI data for Tap gesture for EU 1 is smaller than for NEU 1. C/TCTPI data and D/TCTPI data for Zoom Out gesture and Rotate gesture on EU 1 do not exist, while such data on NEU 1 exist. C/TCTPI data and D/TCTPI data for Zoom In gesture and Select gesture on EU 1 exist, while such data on NEU 1 do not exist. C/TCTPI data and D/TCTPI data for Drag gesture are almost same for both EU 1 and NEU 1. It indicates that EU 1 and NEU 1 were moving around the area and making selections, but EU 1 was more stable than NEU 1 in terms of selections.

4.1.9 TIME INTERVAL 9

Time interval 9 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 1. Figure 23 shows the gaze plots of EU 1 and NEU 1 during Time Interval 9.

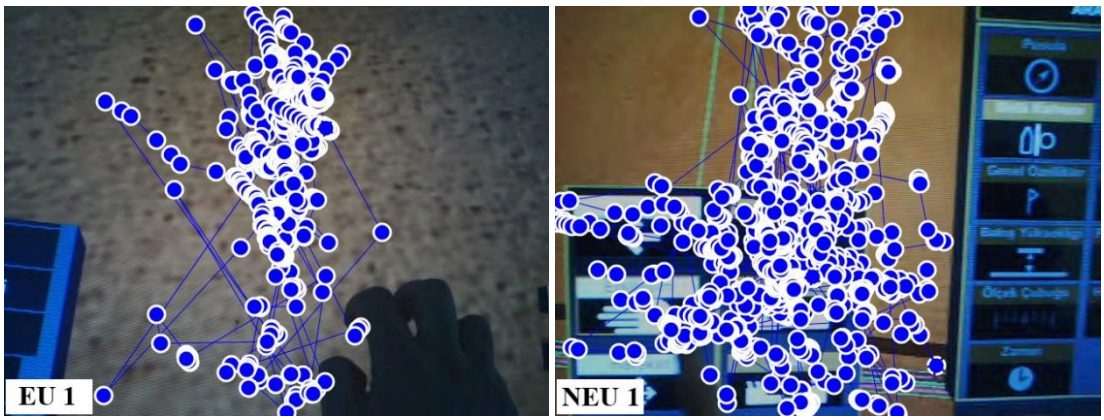


Figure 23 - Test 1: Time Interval 9 - Gaze Plots

Table 32 shows fixation durations and fixation counts of the EU 1 and NEU 1 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 32 - Test 1: Time Interval 9 - Fixation Durations and Fixation Counts

Time Interval 9 (80%-90%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	4.68	14.57	2.73	2.30	24.28
	NEU 1	11.80	6.60	20.57	5.07	44.04
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.142**	**0.443**	0.083	0.070	0.739
	NEU 1	**0.194**	0.108	**0.338**	0.083	0.723
Fixation Count	**EU 1**	141	438	82	69	730
	NEU 1	354	198	618	152	1322
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**4.292**	**13.331**	2.496	2.100	22.219
	NEU 1	**5.814**	3.252	**10.150**	2.497	21.713

As it is seen from the Figure 23, the gaze plots of the EU 1 are mostly on upper center of the screen, while the gaze plots of the NEU 1 are mostly on the center and bottom left side of the screen. It is seen in the Table 32 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1 and AOI 2 are higher than for AOI 3 and AOI 4. However, TFD/TCTPI data and FC/TCTPI data for NEU 1 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on the area which includes objects, while NEU 1 was mostly working on left side of the screen which includes left menu.

Table 33 shows counts and durations of EU 1 and NEU 1 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 33 - Test 1: Time Interval 9 - Tracked Area and Command

Time Interval 9 (80%-90%)		**Tracked Area**			**Command**
		Inside Menu	**Outside Menu**	**Objects**	**Move Command**
Transition Counts	**EU 1**	3	4	3	0
	NEU 1	8	7	1	2
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.091	0.122	**0.091**	0.000
	NEU 1	0.131	0.115	**0.016**	0.033
Durations (sec)	**EU 1**	9.456	23.411	5.215	0.000
	NEU 1	24.160	36.598	0.824	1.477
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.288**	**0.713**	**0.159**	0.000
	NEU 1	**0.397**	**0.601**	**0.014**	0.024

Table 33 shows that TC/TCTPI data and D/TCTPI data for Objects on EU 1 are higher than on NEU 1. On the other hand, the D/TCTPI data of EU 1 and NEU 1 for Outside Menu is higher than the data for Inside Menu. It indicates that both EU 1 and NEU 1 were looking at the out of menu area more than menu area in durations.

During the retrospective review, EU 1 supported this by saying: "I am selecting my target again in the same way and I will give a command on it. Now, I am trying to give a command on a moving object and to define it as target."

> *"Yine ayı şekilde hedefimi seçiyorum ona görev vereceğim. Şu an hareket eden bir nesne üzerine görev vermeye çalışıyorum hedef olarak belirlemeye çalışıyorum." [EU 1]*

NEU 1 also supported this by saying: "I am still taking my vehicle forward because it is far. It is for catching as soon as possible."

> *"Aracımı ilerletiyorum hala daha uzakta olduğu için. Bir an önce yakalamak maksadıyla." [NEU 1]*

Table 34 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 34 - Test 1: Time Interval 9 - Gestures

Time Interval 9 (80%-90%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	7	0	0	4	0	7
	NEU 1	16	1	2	1	1	4
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.213**	**0.000**	**0.000**	**0.122**	**0.000**	**0.213**
	NEU 1	**0.263**	**0.016**	**0.033**	**0.016**	**0.016**	**0.066**
Durations (sec)	**EU 1**	-	0.000	0.000	1.442	0.000	1.853
	NEU 1	-	4.188	3.571	0.344	2.266	3.400
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.000**	**0.000**	**0.044**	**0.000**	**0.056**
	NEU 1	-	**0.069**	**0.059**	**0.006**	**0.037**	**0.056**

As it is seen in the Table 34, C/TCTPI data for Tap gesture is almost same for both EU 1 and NEU 1. C/TCTPI data and D/TCTPI data for Zoom Out gesture, Zoom In gesture and Rotate gesture on EU 1 do not exist, while such data on NEU 1 exist. C/TCTPI data and D/TCTPI data for Select gesture for EU 1 are higher than for NEU 1. C/TCTPI data for Drag gesture for EU 1 is higher than for NEU 1, but D/TCTPI data for Drag gesture is almost same for both EU 1 and NEU 1. It indicates that EU 1 and NEU 1 were moving around the area and making selections.

4.1.10 TIME INTERVAL 10

Time interval 10 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 1. Figure 24 shows the gaze plots of EU 1 and NEU 1 during Time Interval 10.

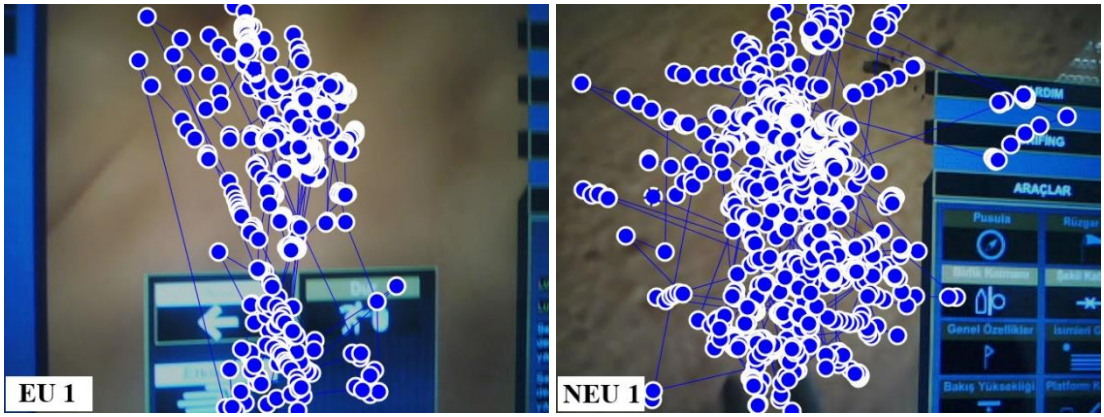


Figure 24 - Test 1: Time Interval 10 - Gaze Plots

Table 35 shows fixation durations and fixation counts of the EU 1 and NEU 1 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 35 - Test 1: Time Interval 10 - Fixation Durations and Fixation Counts

Time Interval 10 (90%-100%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	4.50	12.00	1.77	3.23	21.50
	NEU 1	29.29	6.80	11.40	4.63	52.12
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.137**	**0.365**	0.054	0.098	0.654
	NEU 1	**0.481**	0.112	**0.187**	0.076	0.856
Fixation Count	**EU 1**	135	360	53	97	645
	NEU 1	879	204	342	139	1564
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**4.109**	**10.957**	1.613	2.952	19.632
	NEU 1	**14.437**	3.351	**5.617**	2.283	25.688

As it is seen from the Figure 24, the gaze plots of the EU 1 are mostly on upper center of the screen and bottom center of the screen, while the gaze plots of NEU 1 are mostly on the center and left side of the screen. It is seen in the Table 35 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1 and AOI 2 are higher than for AOI 3 and AOI 4. However, TFD/TCTPI data and FC/TCTPI data for NEU 1 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on upper side of the screen which includes objects, while NEU 1 was mostly working on left side of the screen which includes left menu.

Table 36 shows counts and durations of EU 1 and NEU 1 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 36 - Test 1: Time Interval 10 - Tracked Area and Command

Time Interval 10 (90%-100%)		Tracked Area			Command
		Inside Menu	Outside Menu	Objects	Move Command
Transition Counts	**EU 1**	4	4	6	1
	NEU 1	8	8	12	1
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.122	0.122	**0.183**	0.030
	NEU 1	0.131	0.131	**0.197**	0.016
Durations (sec)	**EU 1**	10.917	21.944	6.905	0.481
	NEU 1	16.252	44.626	19.227	0.652
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.332**	**0.668**	**0.210**	0.015
	NEU 1	**0.267**	**0.733**	**0.316**	0.011

Table 36 shows that TC/TCTPI data for Objects on EU 1 is almost same with on NEU 1, but D/TCTPI data for Objects on EU 1 is smaller than on NEU 1. On the other hand, the D/TCTPI data of EU 1 and NEU 1 for Outside Menu is higher than the data for Inside Menu. It indicates that both EU 1 and NEU 1 were looking at the out of menu area more than menu area in durations.

Table 37 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 37 - Test 1: Time Interval 10 - Gestures

Time Interval 10 (90%-100%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	12	0	3	2	0	11
	NEU 1	21	1	2	0	0	3
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.365**	**0.000**	**0.091**	**0.061**	0.000	**0.335**
	NEU 1	**0.345**	**0.016**	**0.033**	**0.000**	0.000	**0.049**
Durations (sec)	**EU 1**	-	0.000	3.605	0.687	0.000	2.747
	NEU 1	-	1.545	4.601	0.000	0.000	4.360
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.000**	**0.110**	**0.021**	0.000	**0.084**
	NEU 1	-	**0.025**	**0.076**	**0.000**	0.000	**0.072**

As it is seen in the Table 37, C/TCTPI data for Tap gesture is almost same for both EU 1 and NEU 1. C/TCTPI data and D/TCTPI data for Zoom Out gesture on EU 1 do not exist, while such data on NEU 1 exist. C/TCTPI data and D/TCTPI data for Select gesture on EU 1 exist, while such data on NEU 1 do not exist. C/TCTPI data and D/TCTPI data for Zoom In gesture and Drag gesture for EU 1 are higher than for NEU 1. It indicates that EU 1 was moving around the area more than NEU 1 and making selections almost same with NEU 1.

During the retrospective review, EU 1 supported this by saying: "For instance, a little while ago, I realized that I select the object much easier by zooming in more. In order to see it more clearly, I took the camera to up. I am moving through the last point, then the game and mission will be finished. Now, we are completing the mission."

> *"Mesela biraz önce de baya bir yakından nesneyi çok daha kolay seçtiğimi fark ettim. Onu daha net görebilmek için baya bir kamerayı yukarı taşıdım. Son noktasına getiriyorum artık ondan sonra oyunum da sonlanmış olacak görev de bitmiş olacak. Şu an görevi bitiriyoruz." [EU 1]*

Also, NEU 1 supported this by saying: "I took of my soldiers. When I realized smuggler, I chose one of the soldiers. I gave a catch command and I caught. That's it."

> *"Askerlerimi indirdim. Kaçakçıyı fark ettiğimde askerlerden bir tanesini seçtim. Yakala emri verdim ve yakaladım. Bu kadar." [NEU 1]*

4.2 RESULTS OF TEST 2

In order to strengthen the data of Test 1, Test 2 was done with the same expert user (EU 1) and different non-expert user (NEU 2). In other words, Test 2 was conducted in order to enable making consistent connections between the data of expert user and non-expert user during the task.

The results of Test 2 are presented under 10 time intervals as it is seen in the Table 38 for Expert User 1 (EU 1) and Non-Expert User 2 (NEU 2). There is a subheading for each time interval for Test 2. The gaze plot data and eye tracking data are presented for the each time interval.

Table 38 - Test 2: Time Intervals Distribution

	EU 1		NEU 2	
	Start Time (sec)	**Finish Time (sec)**	**Start Time (sec)**	**Finish Time (sec)**
Total Task Duration (0%-100%)	0.000	588.133	0.000	671.036
Time Interval 1 (0%-10%)	0.000	58.813	0.000	67.104
Time Interval 2 (10%-20%)	58.813	117.627	67.104	134.207
Time Interval 3 (20%-30%)	117.627	176.440	134.207	201.311
Time Interval 4 (30%-40%)	176.440	235.253	201.311	268.414
Time Interval 5 (40%-50%)	235.253	294.067	268.414	335.518
Time Interval 6 (50%-60%)	294.067	352.880	335.518	402.622
Time Interval 7 (60%-70%)	352.880	411.693	402.622	469.725
Time Interval 8 (70%-80%)	411.693	470.506	469.725	536.829
Time Interval 9 (80%-90%)	470.506	529.320	536.829	603.932
Time Interval 10 (90%-100%)	529.320	588.133	603.932	671.036

Each time interval for Expert User 1 (EU 1) consists of 58.813 seconds and the total task duration of the EU 1 is 588.133 seconds. Each time interval for Non-Expert User 2 (NEU 2) consists of 67.104 seconds and the total task duration of the NEU 2 is 671.036 seconds.

4.2.1 TIME INTERVAL 1

Time interval 1 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 2. Figure 25 shows the gaze plots of EU 1 and NEU 2 during Time Interval 1.

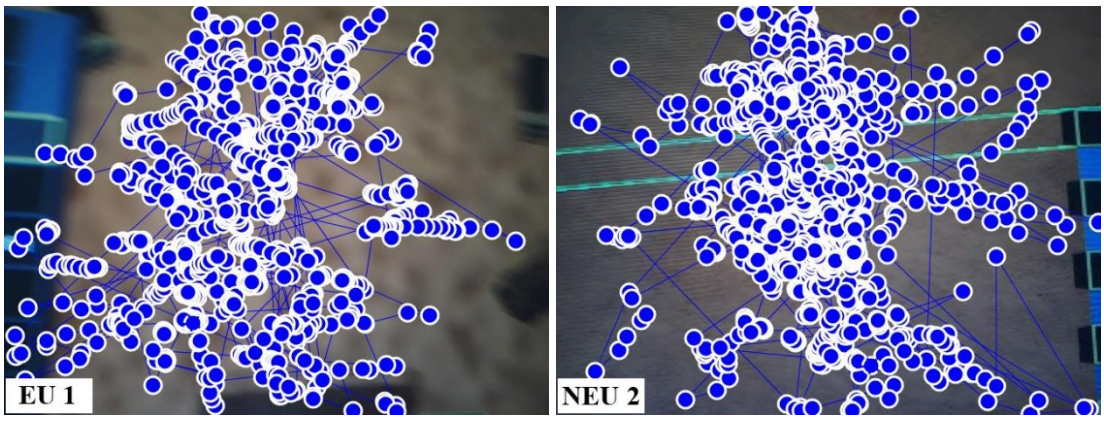


Figure 25 - Test 2: Time Interval 1 - Gaze Plots

Table 39 shows fixation durations and fixation counts of the EU 1 and NEU 2 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 39 - Test 2: Time Interval 1 - Fixation Durations and Fixation Counts

Time Interval 1 (0%-10%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	13.47	10.57	13.35	5.83	43.22
	NEU 2	20.91	9.87	17.07	10.71	58.56
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.229**	0.180	**0.227**	0.099	0.735
	NEU 2	**0.312**	0.147	**0.254**	0.160	0.873
Fixation Count	**EU 1**	404	318	401	175	1298
	NEU 2	628	296	512	322	1758
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**6.869**	5.407	**6.818**	2.976	22.070
	NEU 2	**9.359**	4.411	**7.630**	4.799	26.198

As it is seen from the Figure 25, the gaze plots of the EU 1 are mostly left side of the screen, while the gaze plots of the NEU 2 are mostly on the upper center of the screen. As it is seen in the Table 39, TFD/TCTPI data and FC/TCTPI data of both EU 1 and NEU 2 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that both EU 1 and NEU 2 were preparing for the task by checking menus and objects on the screen.

Table 40 shows counts and durations of EU 1 and NEU 2 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 40 - Test 2: Time Interval 1 - Tracked Area and Command

Time Interval 1 (0%-10%)		**Tracked Area**			**Command**
		Inside Menu	**Outside Menu**	**Objects**	**Move Command**
Transition Counts	**EU 1**	10	10	16	0
	NEU 2	7	7	7	0
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.170	0.170	**0.272**	0.000
	NEU 2	0.104	0.104	**0.104**	0.000
Durations (sec)	**EU 1**	27.874	30.935	14.318	0.000
	NEU 2	36.401	30.694	6.351	0.000
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.474**	**0.526**	**0.243**	0.000
	NEU 2	**0.542**	**0.457**	**0.095**	0.000

Table 40 shows that TC/TCTPI data and D/TCTPI data for Objects on EU 1 are higher than on NEU 2. On the other hand, the D/TCTPI data difference between Inside Menu and Outside Menu is almost equal for both EU 1 and NEU 2. It indicates that both EU 1 and NEU 2 were looking at the menu area and out of menu area with almost equal durations.

Table 41 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 41 - Test 2: Time Interval 1 - Gestures

Time Interval 1 (0%-10%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	30	2	1	0	0	1
	NEU 2	28	2	0	0	1	1
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.510**	**0.034**	**0.017**	0.000	**0.000**	**0.017**
	NEU 2	**0.417**	**0.030**	**0.000**	0.000	**0.015**	**0.015**
Durations (sec)	**EU 1**	-	2.472	0.446	0.000	0.000	1.099
	NEU 2	-	5.288	0.000	0.000	1.236	0.789
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.042**	**0.008**	0.000	**0.000**	**0.019**
	NEU 2	-	**0.079**	**0.000**	0.000	**0.018**	**0.012**

As it is seen in the Table 41, C/TCTPI data for Tap gesture for EU 1 is a little bit higher than for NEU 2. C/TCTPI data for Zoom Out gesture on EU 1 is a little bit higher than for NEU 2, but D/TCTPI data for Zoom Out gesture on EU 1 is smaller than on NEU 2. C/TCTPI data and D/TCTPI data for Drag gesture for EU 1 is higher than for NEU 2. While C/TCTPI data and D/TCTPI data for Zoom In gesture exist for only EU 1, C/TCTPI data and D/TCTPI data for Rotate gesture exist for only NEU 2. It indicates that both EU 1 and NEU 2 explored the objects and the area mostly by tapping from menu and using area.

4.2.2 TIME INTERVAL 2

Time interval 2 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 2. Figure 26 shows the gaze plots of EU 1 and NEU 2 during Time Interval 2.

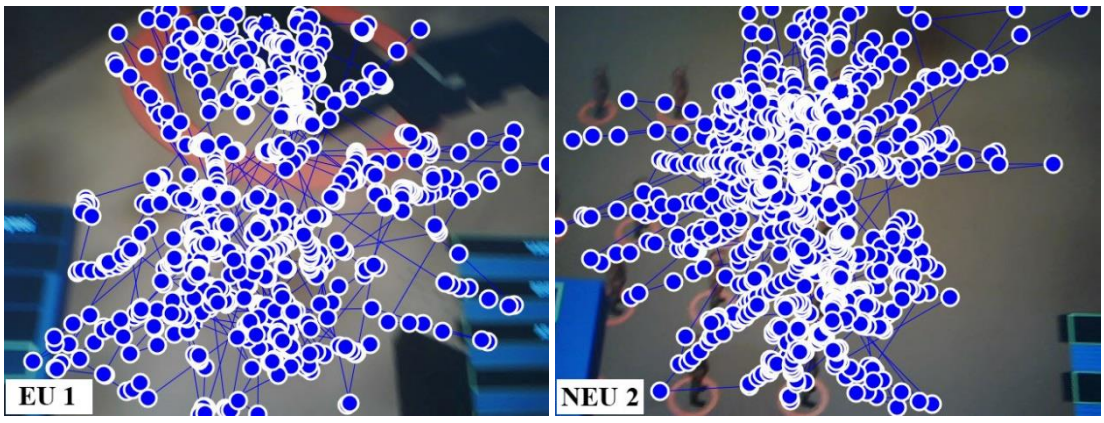


Figure 26 - Test 2: Time Interval 2 - Gaze Plots

Table 42 shows fixation durations and fixation counts of the EU 1 and NEU 2 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 42 - Test 2: Time Interval 2 - Fixation Durations and Fixation Counts

Time Interval 2 (10%-20%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	8.84	9.67	12.88	5.23	36.62
	NEU 2	30.80	9.17	11.17	9.49	60.63
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.150**	**0.164**	**0.219**	0.089	0.623
	NEU 2	**0.459**	0.137	**0.166**	0.141	0.904
Fixation Count	**EU 1**	266	290	387	157	1100
	NEU 2	924	276	335	285	1820
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**4.523**	**4.931**	**6.580**	2.669	18.703
	NEU 2	**13.770**	4.113	**4.992**	4.247	27.122

As it is seen from the Figure 26, the gaze plots of the EU 1 are spread around the screen, while the gaze plots of the NEU 2 are mostly on the left side of the screen. It is seen in the Table 42 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1, AOI 2 and AOI 3 are higher than for AOI 4. However, TFD/TCTPI data and FC/TCTPI data for NEU 2 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on out of menu which includes objects on the area, while NEU 2 was mostly working on left side of the screen which includes left menu.

Table 43 shows counts and durations of EU 1 and NEU 2 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 43 - Test 2: Time Interval 2 - Tracked Area and Command

Time Interval 2 (10%-20%)		Tracked Area			Command
		Inside Menu	Outside Menu	Objects	Move Command
Transition Counts	**EU 1**	8	8	2	3
	NEU 2	12	12	9	0
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.136	0.136	**0.034**	0.051
	NEU 2	0.179	0.179	**0.134**	0.000
Durations (sec)	**EU 1**	31.453	27.363	2.781	2.061
	NEU 2	35.870	31.255	10.917	0.000
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.535**	**0.465**	**0.047**	0.035
	NEU 2	**0.535**	**0.466**	**0.163**	0.000

Table 43 shows that TC/TCTPI data and D/TCTPI data for Objects on EU 1 are higher than on NEU 2. On the other hand, the D/TCTPI data difference between Inside Menu and Outside Menu is almost equal for both EU 1 and NEU 2. It indicates that both EU 1 and NEU 2 were looking at the menu area and out of menu area with almost equal durations.

Table 44 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 44 - Test 2: Time Interval 2 - Gestures

Time Interval 2 (10%-20%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	24	3	0	0	0	9
	NEU 2	45	1	1	0	0	2
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.408**	**0.051**	**0.000**	0.000	0.000	**0.153**
	NEU 2	**0.671**	**0.015**	**0.015**	0.000	0.000	**0.030**
Durations (sec)	**EU 1**	-	2.438	0.000	0.000	0.000	4.841
	NEU 2	-	1.922	2.747	0.000	0.000	1.133
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.041**	0.000	0.000	0.000	**0.082**
	NEU 2	-	**0.029**	0.041	0.000	0.000	**0.017**

As it is seen in the Table 44, C/TCTPI data for Tap gesture for EU 1 is smaller than for NEU 2, but C/TCTPI data and D/TCTPI data for Zoom Out gesture and Drag gesture for EU 1 is higher than for NEU 2. Also, C/TCTPI data and D/TCTPI data for Zoom In gesture for NEU 2 exist, while such data for EU 1 do not exist. It indicates that EU 1 explored the objects and area mostly by using Zoom Out gesture and Drag gesture, while NEU 2 explored the objects and the area mostly by tapping from menu.

4.2.3 TIME INTERVAL 3

Time interval 3 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 2. Figure 27 shows the gaze plots of EU 1 and NEU 2 during Time Interval 3.

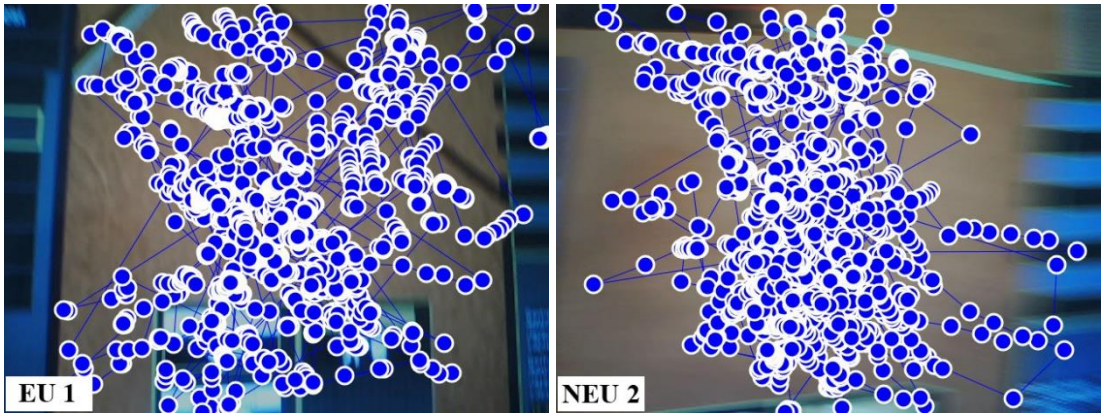


Figure 27 - Test 2: Time Interval 3 - Gaze Plots

Table 45 shows fixation durations and fixation counts of the EU 1 and NEU 2 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 45 - Test 2: Time Interval 3 - Fixation Durations and Fixation Counts

Time Interval 3 (20%-30%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	13.39	13.23	10.10	10.40	47.12
	NEU 2	17.90	10.35	21.03	10.73	60.01
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.228**	**0.225**	0.172	0.177	0.801
	NEU 2	**0.267**	0.154	**0.313**	0.160	0.894
Fixation Count	**EU 1**	402	397	303	312	1414
	NEU 2	537	311	631	322	1801
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**6.835**	**6.750**	5.152	5.305	24.042
	NEU 2	**8.003**	4.635	**9.403**	4.799	26.839

As it is seen from the Figure 27, the gaze plots of the EU 1 are spread around the screen, while the gaze plots of the NEU 2 are mostly on the center of the screen. It is seen in the Table 45 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1 and AOI 2 are higher than for AOI 3 and AOI 4. However, TFD/TCTPI data and FC/TCTPI data for NEU 2 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on out of menu which includes objects on the area, while NEU 2 was mostly working on left side of the screen which includes left menu.

Table 46 shows counts and durations of EU 1 and NEU 2 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 46 - Test 2: Time Interval 3 - Tracked Area and Command

Time Interval 2 (20%-30%)		Tracked Area			Command
		Inside Menu	Outside Menu	Objects	Move Command
Transition Counts	**EU 1**	5	6	5	3
	NEU 2	7	7	4	2
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.085	0.102	**0.085**	0.051
	NEU 2	0.104	0.104	**0.060**	0.030
Durations (sec)	**EU 1**	10.814	48.016	7.089	1.786
	NEU 2	36.802	30.304	7.965	1.716
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.184**	**0.816**	**0.121**	0.030
	NEU 2	**0.548**	**0.452**	**0.119**	0.026

Table 46 shows that TC/TCTPI data and D/TCTPI data are almost equal for both EU 1 and NEU 2. On the other hand, the D/TCTPI data difference between Inside Menu and Outside Menu for EU 1 is higher than the difference for NEU 2. It indicates that EU 1 was looking at out of menu area more than menu area, while NEU 2 was concentrating on menu area and out of menu area with almost equal durations.

Table 47 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 47 - Test 2: Time Interval 3 - Gestures

Time Interval 3 (20%-30%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	11	4	3	1	0	11
	NEU 2	26	2	0	0	0	7
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.187**	**0.068**	**0.051**	**0.017**	0.000	**0.187**
	NEU 2	**0.387**	**0.030**	**0.000**	**0.000**	0.000	**0.104**
Durations (sec)	**EU 1**	-	7.656	3.742	0.275	0.000	12.566
	NEU 2	-	4.120	0.000	0.000	0.000	7.278
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.130**	**0.064**	**0.005**	0.000	**0.214**
	NEU 2	-	**0.061**	**0.000**	**0.000**	0.000	**0.108**

As it is seen in the Table 47, C/TCTPI data for Tap gesture on EU 1 is very smaller than on NEU 2. C/TCTPI data and D/TCTPI data for Zoom Out gesture exist only for NEU 2. C/TCTPI data and D/TCTPI data for Zoom Out gesture and Drag gesture for EU 1 is higher than for NEU 2. Also, C/TCTPI data and D/TCTPI data for Zoom In gesture for EU 1 exist, while such data for NEU 2 do not exist. It indicates that EU 1 explored the objects and area mostly by using Zoom Out gesture and Drag gesture, while NEU 2 explored the objects and the area mostly by tapping from menu.

4.2.4 TIME INTERVAL 4

Time interval 4 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 2. Figure 28 shows the gaze plots of EU 1 and NEU 2 during Time Interval 4.

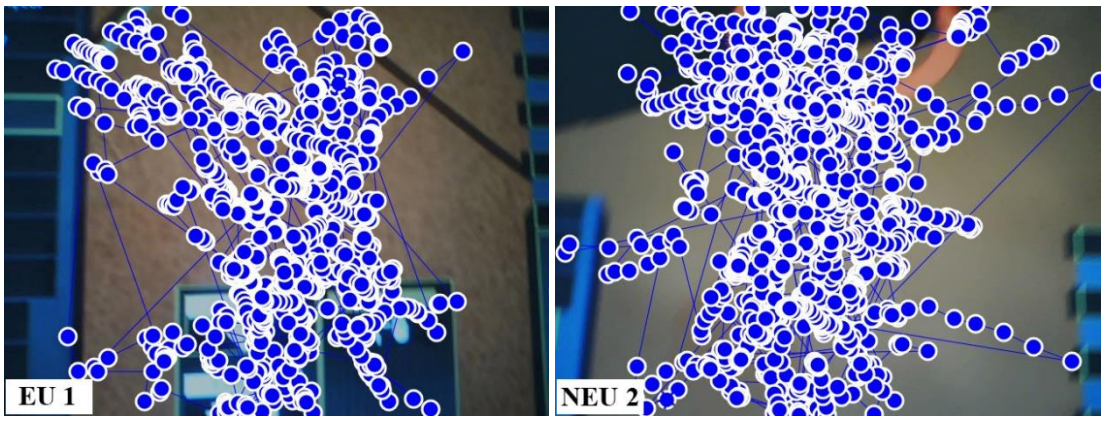


Figure 28 - Test 2: Time Interval 4 - Gaze Plots

Table 48 shows fixation durations and fixation counts of the EU 1 and NEU 2 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 48 - Test 2: Time Interval 4 - Fixation Durations and Fixation Counts

Time Interval 4 (30%-40%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	13.17	10.92	9.13	10.77	43.99
	NEU 2	26.10	10.64	13.23	9.03	59.00
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.224**	**0.186**	0.155	**0.183**	0.748
	NEU 2	**0.389**	0.159	**0.197**	0.135	0.879
Fixation Count	**EU 1**	396	328	274	323	1321
	NEU 2	783	320	397	271	1771
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**6.733**	**5.577**	4.659	**5.492**	22.461
	NEU 2	**11.668**	4.769	**5.916**	4.039	20.476

As it is seen from the Figure 28, the gaze plots of the EU 1 and NEU 2 are mostly on the upper center of the screen. It is seen in the Table 48 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1, AOI 2 and AOI 4 are higher than for AOI 3. However, TFD/TCTPI data and FC/TCTPI data for NEU 2 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on right side of the screen which includes right menu and upper side of the screen which includes objects, while NEU 2 was mostly working on left side of the screen which includes left menu.

Table 49 shows counts and durations of EU 1 and NEU 2 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 49 - Test 2: Time Interval 4 - Tracked Area and Command

Time Interval 4 (30%-40%)		**Tracked Area**			**Command**
		Inside Menu	**Outside Menu**	**Objects**	**Move Command**
Transition Counts	**EU 1**	5	6	10	3
	NEU 2	9	8	12	3
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.085	0.102	**0.170**	0.051
	NEU 2	0.134	0.119	**0.179**	0.045
Durations (sec)	**EU 1**	13.366	45.448	13.991	1.785
	NEU 2	20.401	46.694	12.325	1.991
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.227**	**0.773**	**0.238**	0.030
	NEU 2	**0.304**	**0.696**	**0.184**	0.030

Table 49 shows that TC/TCTPI data and D/TCTPI data for Objects are almost equal on both EU 1 and NEU 2. On the other hand, the D/TCTPI data difference between Inside Menu and Outside Menu is almost equal for both EU 1 and NEU 2. It indicates that both EU 1 and NEU 2 were looking at the out of menu area which includes objects more than menu area.

Table 50 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 50 - Test 2: Time Interval 4 - Gestures

Time Interval 4 (30%-40%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	16	2	4	3	0	7
	NEU 2	15	3	0	3	0	9
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.272**	**0.034**	**0.068**	**0.051**	0.000	**0.119**
	NEU 2	**0.224**	**0.045**	**0.000**	**0.045**	0.000	**0.134**
Durations (sec)	**EU 1**	-	2.747	4.635	0.961	0.000	6.557
	NEU 2	-	5.871	0.000	0.858	0.000	10.781
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.047**	**0.079**	**0.016**	0.000	**0.111**
	NEU 2	-	**0.087**	**0.000**	**0.013**	0.000	**0.161**

As it is seen in the Table 50, C/TCTPI data for Tap gesture on EU 1 is higher than on NEU 2. C/TCTPI data and D/TCTPI data for Zoom Out gesture and Drag gesture on EU 1 are smaller than on NEU 2. However, C/TCTPI data and D/TCTPI data for Select gesture on EU 1 are higher than on NEU 2. Also, C/TCTPI data and D/TCTPI data for Zoom In gesture for EU 1 exist, while such data for NEU 2 do not exist. It indicates that EU 1 and NEU 2 were moving around the area and making selections between menus by tapping, but EU 1 was tapping more than NEU 2.

4.2.5 TIME INTERVAL 5

Time interval 5 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 2. Figure 29 shows the gaze plots of EU 1 and NEU 2 during Time Interval 5.

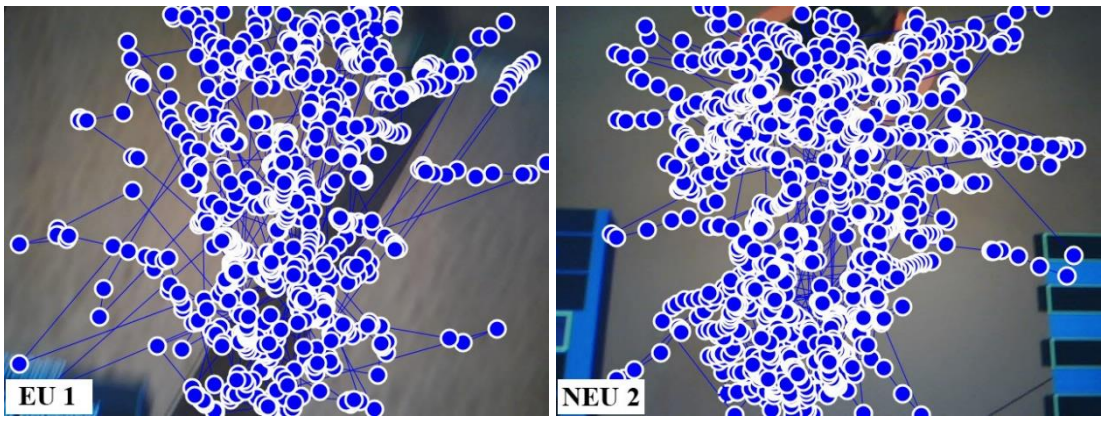


Figure 29 - Test 2: Time Interval 5 - Gaze Plots

Table 51 shows fixation durations and fixation counts of the EU 1 and NEU 2 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 51 - Test 2: Time Interval 5 - Fixation Durations and Fixation Counts

Time Interval 5 (40%-50%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	6.90	13.96	9.77	7.60	38.23
	NEU 2	16.99	13.73	17.03	8.63	56.38
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	0.117	**0.237**	**0.166**	0.129	0.650
	NEU 2	**0.253**	0.205	**0.254**	0.129	0.840
Fixation Count	**EU 1**	207	420	293	228	1148
	NEU 2	510	412	511	259	1692
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	3.520	**7.141**	**4.982**	3.877	19.519
	NEU 2	**7.600**	6.140	**7.615**	3.860	25.215

As it is seen from the Figure 29, the gaze plots of both EU 1 and NEU 2 are mostly on the upper center of the screen. It is seen in the Table 51 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 2 and AOI 3 are higher than for AOI 1 and AOI 4. However, TFD/TCTPI data and FC/TCTPI data for NEU 2 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on upper right side of the screen which includes objects, while NEU 2 was mostly working on left side of the screen which includes left menu.

Table 52 shows counts and durations of EU 1 and NEU 2 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 52 - Test 2: Time Interval 5 - Tracked Area and Command

Time Interval 5 (40%-50%)		**Tracked Area**			**Command**
		Inside Menu	**Outside Menu**	**Objects**	**Move Command**
Transition Counts	**EU 1**	8	9	9	4
	NEU 2	11	11	13	4
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.136	0.153	**0.153**	0.068
	NEU 2	0.164	0.164	**0.194**	0.060
Durations (sec)	**EU 1**	12.739	46.054	10.403	2.094
	NEU 2	24.028	43.064	13.435	2.473
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.217**	**0.783**	**0.177**	0.036
	NEU 2	**0.358**	**0.642**	**0.200**	0.037

Table 52 shows that TC/TCTPI data and D/TCTPI data for Objects on EU 1 are smaller than on NEU 2. On the other hand, the D/TCTPI data difference between Inside Menu and Outside Menu for EU 1 is higher than the difference for NEU 2. It indicates that while EU 1 was looking at out of menu area more than NEU 2.

Table 53 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 53 - Test 2: Time Interval 5 - Gestures

Time Interval 5 (40%-50%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	9	3	2	2	0	13
	NEU 2	27	3	0	1	0	8
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.153**	**0.051**	**0.034**	**0.034**	0.000	**0.221**
	NEU 2	**0.402**	**0.045**	**0.000**	**0.015**	0.000	**0.119**
Durations (sec)	**EU 1**	-	4.052	2.609	0.721	0.000	8.581
	NEU 2	-	5.939	0.000	0.309	0.000	9.031
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.069**	**0.044**	**0.012**	0.000	**0.146**
	NEU 2	-	**0.089**	**0.000**	**0.005**	0.000	**0.135**

As it is seen in the Table 53, C/TCTPI data for Tap gesture for EU 1 is smaller than for NEU 2. C/TCTPI data for Zoom Out gesture on EU 1 is a little bit higher than on NEU 2, but D/TCTPI data for Zoom Out gesture on EU 1 is smaller than on NEU 2. C/TCTPI data and D/TCTPI data for Select gesture and Drag gesture on EU 1 is higher than on NEU 2. Also, C/TCTPI data and D/TCTPI data for Zoom In gesture for EU 1 exist, while such data for NEU 2 do not exist. It indicates that EU 1 was mostly moving around the area and working on objects, while NEU 2 was mostly moving around the area and making selections between menus by using Tap gesture more.

4.2.6 TIME INTERVAL 6

Time interval 6 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 2. Figure 30 shows the gaze plots of EU 1 and NEU 2 during Time Interval 6.

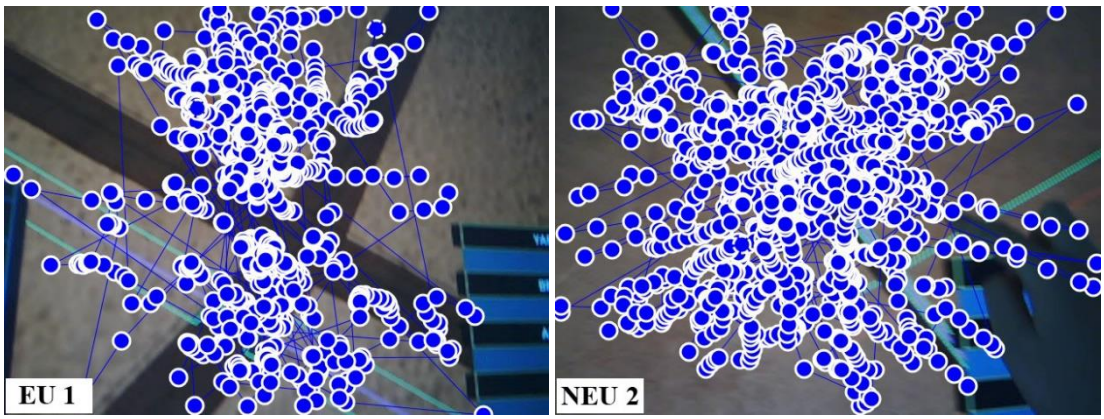


Figure 30 - Test 2: Time Interval 6 - Gaze Plots

Table 54 shows fixation durations and fixation counts of the EU 1 and NEU 2 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 54 - Test 2: Time Interval 6 - Fixation Durations and Fixation Counts

Time Interval 6 (50%-60%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	19.36	7.56	9.17	5.57	41.66
	NEU 2	22.17	19.77	12.17	6.57	60.68
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.329**	0.129	**0.156**	0.095	0.708
	NEU 2	**0.330**	**0.295**	0.181	0.098	0.904
Fixation Count	**EU 1**	581	227	275	167	1250
	NEU 2	666	593	365	197	1821
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**9.879**	3.860	**4.676**	2.840	21.254
	NEU 2	**9.925**	**8.837**	5.439	2.936	27.137

As it is seen from the Figure 30, the gaze plots of the EU 1 are mostly on the upper center of the screen, while the gaze plots of the NEU 2 are mostly on the left side of the screen. It is seen in the Table 54 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1 and AOI 3 are higher than for AOI 2 and AOI 4. However, TFD/TCTPI data and FC/TCTPI data for NEU 2 on AOI 1 and AOI 2 are higher than the data on AOI 3 and AOI 4. This indicates that EU 1 was mostly working on left side of the screen which includes left menu, while NEU 2 was mostly working on upper side of the screen which includes objects.

Table 55 shows counts and durations of EU 1 and NEU 2 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 55 - Test 2: Time Interval 6 - Tracked Area and Command

Time Interval 6 (50%-60%)		Tracked Area			Command
		Inside Menu	Outside Menu	Objects	Move Command
Transition Counts	**EU 1**	10	11	9	3
	NEU 2	2	3	5	0
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.170	0.187	**0.153**	0.051
	NEU 2	0.030	0.045	**0.075**	0.000
Durations (sec)	**EU 1**	17.033	41.796	16.105	1.853
	NEU 2	4.841	62.256	1.808	0.000
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	0.290	0.711	**0.274**	0.032
	NEU 2	0.072	0.928	**0.027**	0.000

Table 55 shows that TC/TCTPI data and D/TCTPI data for Objects on EU 1 are higher than on NEU 2. On the other hand, the D/TCTPI data of EU 1 and NEU 2 for Outside Menu is higher than the data for Inside Menu. It indicates that both EU 1 and NEU 2 were looking at the out of menu area more than menu area in durations.

Table 56 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 56 - Test 2: Time Interval 6 - Gestures

Time Interval 6 (50%-60%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	14	2	3	2	0	8
	NEU 2	5	2	4	0	0	9
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.238**	**0.034**	**0.051**	**0.034**	0.000	**0.136**
	NEU 2	**0.075**	**0.030**	**0.060**	**0.000**	0.000	**0.134**
Durations (sec)	**EU 1**	-	3.673	4.086	0.446	0.000	4.121
	NEU 2	-	2.334	8.582	0.000	0.000	16.686
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.062**	**0.069**	**0.008**	0.000	**0.070**
	NEU 2	-	**0.035**	**0.128**	**0.000**	0.000	**0.249**

As it is seen in the Table 56, C/TCTPI data for Tap gesture for EU 1 is higher than for NEU 2. C/TCTPI data and D/TCTPI data for Zoom Out gesture on EU 1 is higher than on NEU 2. C/TCTPI data for Zoom In gesture for EU 1 is smaller than for NEU 2. C/TCTPI data and D/TCTPI data for Select gesture for EU 1 exist, while such data for NEU 2 do not exist. C/TCTPI data for Drag gesture on EU 1 is a little bit higher than on NEU 2, but D/TCTPI data for Drag gesture on EU 1 is smaller than on NEU 2. It indicates that EU 1 was mostly moving around the area and making selections between menus by using Tap gesture more, while NEU 2 was mostly moving around the area and working on objects.

4.2.7 TIME INTERVAL 7

Time interval 7 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 2. Figure 31 shows the gaze plots of EU 1 and NEU 2 during Time Interval 7.

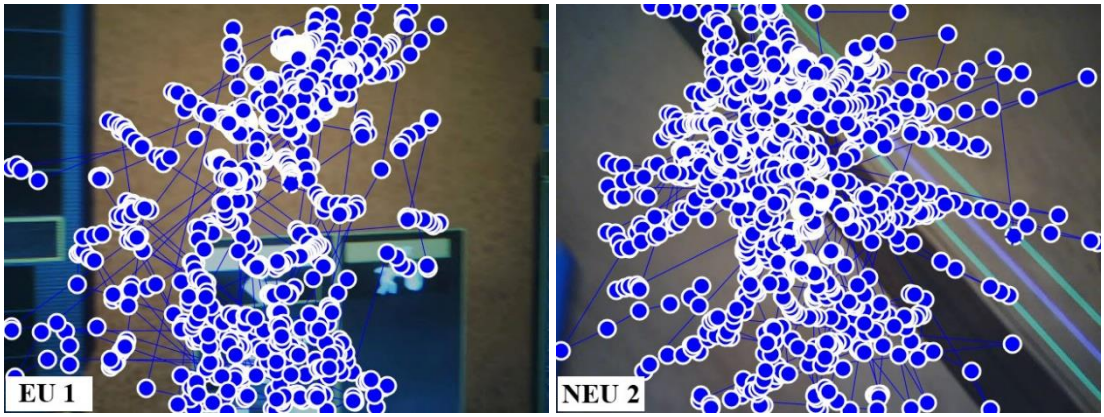


Figure 31 - Test 2: Time Interval 7 - Gaze Plots

Table 57 shows fixation durations and fixation counts of the EU 1 and NEU 2 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 57 - Test 2: Time Interval 7 - Fixation Durations and Fixation Counts

Time Interval 7 (60%-70%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	10.54	14.92	9.93	6.17	41.56
	NEU 2	32.33	7.30	12.57	5.77	57.97
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.179**	**0.254**	0.169	0.105	0.707
	NEU 2	**0.482**	0.109	**0.187**	0.086	0.864
Fixation Count	**EU 1**	317	448	298	185	1248
	NEU 2	970	219	378	173	1740
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**5.390**	**7.617**	5.067	3.146	21.220
	NEU 2	**14.455**	3.264	**5.633**	2.578	25.930

As it is seen from the Figure 31, the gaze plots of the EU 1 are mostly on upper side of the screen, while the gaze plots of the NEU 2 are mostly on left side of the screen. It is seen in the Table 57 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1 and AOI 2 are higher than for AOI 3 and AOI 4. However, TFD/TCTPI data and FC/TCTPI data for NEU 2 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on upper side of the screen which includes objects, while NEU 2 was mostly working on left side of the screen which includes left menu.

Table 58 shows counts and durations of EU 1 and NEU 2 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 58 - Test 2: Time Interval 7 - Tracked Area and Command

Time Interval 7 (60%-70%)		**Tracked Area**			**Command**
		Inside Menu	**Outside Menu**	**Objects**	**Move Command**
Transition Counts	**EU 1**	5	6	3	4
	NEU 2	6	7	3	3
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.085	0.102	**0.051**	0.068
	NEU 2	0.089	0.104	**0.045**	0.045
Durations (sec)	**EU 1**	21.457	37.355	5.355	2.918
	NEU 2	19.123	47.976	1.201	1.991
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.365**	**0.635**	**0.091**	0.050
	NEU 2	**0.285**	**0.715**	**0.018**	0.030

Table 58 shows that TC/TCTPI data and D/TCTPI data for Objects on EU 1 are higher than on NEU 2. On the other hand, the D/TCTPI data of EU 1 and NEU 2 for Outside Menu is higher than the data for Inside Menu. It indicates that both EU 1 and NEU 2 were looking at the out of menu area more than menu area in durations.

Table 59 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 59 - Test 2: Time Interval 7 - Gestures

Time Interval 7 (60%-70%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	30	2	0	2	0	8
	NEU 2	17	1	2	0	0	14
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.510**	**0.034**	**0.000**	**0.034**	0.000	**0.136**
	NEU 2	**0.253**	**0.015**	**0.030**	**0.000**	0.000	**0.209**
Durations (sec)	**EU 1**	-	1.991	0.000	1.648	0.000	9.545
	NEU 2	-	1.065	2.008	0.000	0.000	14.316
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.034**	**0.000**	**0.028**	0.000	**0.162**
	NEU 2	-	**0.016**	**0.030**	**0.000**	0.000	**0.213**

As it is seen in the Table 59, C/TCTPI data for Tap gesture for EU 1 is higher than for NEU 2. C/TCTPI data and D/TCTPI data for Zoom Out gesture on EU 1 are higher than on NEU 2. C/TCTPI data and D/TCTPI data for Zoom In gesture on EU 1 do not exist, while such data on NEU 2 exist. C/TCTPI data and D/TCTPI data for Select gesture on EU 1 exist, while such data on NEU 2 do not exist. C/TCTPI data and D/TCTPI data for Drag gesture on EU 1 are smaller than on NEU 2. It indicates that both EU 1 and NEU 2 were mostly moving around the area and making selections between menus and area of objects, but EU 1 was using Tap gesture more than NEU 2.

4.2.8 TIME INTERVAL 8

Time interval 8 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 2. Figure 32 shows the gaze plots of EU 1 and NEU 2 during Time Interval 8.

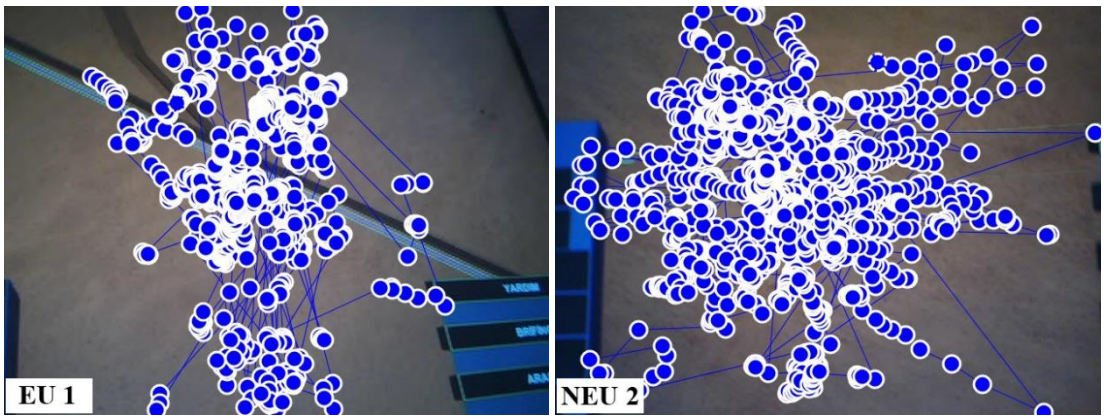


Figure 32 - Test 2: Time Interval 8 - Gaze Plots

Table 60 shows fixation durations and fixation counts of the EU 1 and NEU 2 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 60 - Test 2: Time Interval 8 - Fixation Durations and Fixation Counts

Time Interval 8 (70%-80%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	23.54	9.15	8.27	4.97	45.93
	NEU 2	33.70	7.85	15.70	5.07	62.32
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.400**	**0.156**	0.141	0.085	0.781
	NEU 2	**0.502**	0.117	**0.234**	0.076	0.929
Fixation Count	**EU 1**	707	275	248	149	1379
	NEU 2	1011	236	471	152	1870
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**12.021**	**4.676**	4.217	2.533	23.447
	NEU 2	**15.066**	3.517	**7.019**	2.265	27.867

As it is seen from the Figure 32, the gaze plots of the EU 1 are mostly on the upper side of the screen, while the gaze plots of the NEU 2 are mostly on the center and left side of the screen. It is seen in the Table 60 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1 and AOI 2 are higher than for AOI 3 and AOI 4. However, TFD/TCTPI data and FC/TCTPI data for NEU 2 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on upper side of the screen which includes objects, while NEU 2 was mostly working on left side of the screen which includes left menu.

Table 61 shows counts and durations of EU 1 and NEU 2 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 61 - Test 2: Time Interval 8 - Tracked Area and Command

Time Interval 8 (70%-80%)		Tracked Area			Command
		Inside Menu	Outside Menu	Objects	Move Command
Transition Counts	**EU 1**	5	6	13	4
	NEU 2	8	9	8	0
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.085	0.102	**0.221**	0.068
	NEU 2	0.119	0.134	**0.119**	0.000
Durations (sec)	**EU 1**	10.093	48.706	27.225	2.232
	NEU 2	10.883	56.235	9.166	0.000
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.172**	**0.828**	**0.463**	0.038
	NEU 2	**0.162**	**0.838**	**0.137**	0.000

Table 61 shows that TC/TCTPI data and D/TCTPI data for Objects on EU 1 are higher than on NEU 2. On the other hand, the D/TCTPI data of EU 1 and NEU 2 for Outside Menu is higher than the data for Inside Menu. It indicates that both EU 1 and NEU 2 were looking at the out of menu area more than menu area in durations.

Table 62 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 62 - Test 2: Time Interval 8 - Gestures

Time Interval 8 (70%-80%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	10	1	3	2	0	7
	NEU 2	13	3	4	1	0	12
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.170**	**0.017**	**0.051**	0.034	0.000	**0.119**
	NEU 2	**0.194**	**0.045**	**0.060**	0.015	0.000	**0.179**
Durations (sec)	**EU 1**	-	1.442	4.211	0.824	0.000	9.544
	NEU 2	-	6.558	6.987	0.584	0.000	13.986
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.025**	**0.072**	0.014	0.000	**0.162**
	NEU 2	-	**0.098**	**0.104**	0.009	0.000	**0.208**

As it is seen in the Table 62, C/TCTPI data for Tap gesture for EU 1 is smaller than for NEU 2. C/TCTPI data and D/TCTPI data for Zoom Out gesture, Zoom In gesture and Drag gesture on EU 1 are higher than on NEU 2. However, C/TCTPI data and D/TCTPI data for Select gesture on EU 1 are smaller than on NEU 2. It indicates that EU 1 and NEU 2 were moving around the area and making selections, but EU 1 was more active than NEU 2 in terms of selections.

4.2.9 TIME INTERVAL 9

Time interval 9 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 2. Figure 33 shows the gaze plots of EU 1 and NEU 2 during Time Interval 9.

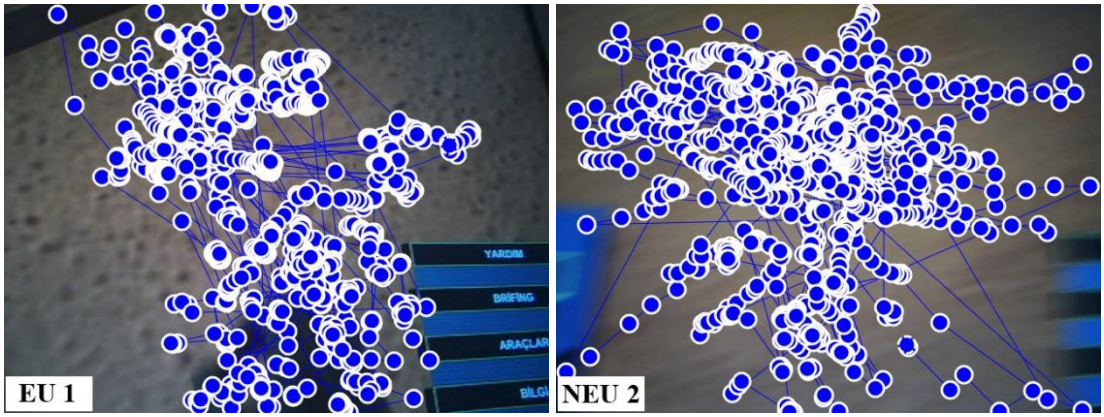


Figure 33 - Test 2: Time Interval 9 - Gaze Plots

Table 63 shows fixation durations and fixation counts of the EU 1 and NEU 2 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 63 - Test 2: Time Interval 9 - Fixation Durations and Fixation Counts

Time Interval 9 (80%-90%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	21.16	9.19	5.93	9.87	46.15
	NEU 2	33.07	16.88	7.50	4.74	62.19
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.360**	0.156	0.101	**0.168**	0.785
	NEU 2	**0.493**	**0.252**	0.112	0.071	0.927
Fixation Count	**EU 1**	635	276	178	296	1385
	NEU 2	992	507	225	143	1867
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**10.797**	4.693	3.027	**5.033**	23.549
	NEU 2	**14.783**	**7.555**	3.353	2.131	25.691

As it is seen from the Figure 33, the gaze plots of the EU 1 are mostly on upper left of the screen, while the gaze plots of the NEU 2 are mostly on upper center of the screen. It is seen in the Table 63 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1 and AOI 4 are higher than for AOI 2 and AOI 3. However, TFD/TCTPI data and FC/TCTPI data for NEU 2 on AOI 1 and AOI 2 are higher than the data on AOI 3 and AOI 4. This indicates that EU 1 was mostly working on the area which includes objects, left menu and right menu, while NEU 2 was mostly working on upper side of the screen which includes objects.

Table 64 shows counts and durations of EU 1 and NEU 2 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 64 - Test 2: Time Interval 9 - Tracked Area and Command

Time Interval 9 (80%-90%)		**Tracked Area**			**Command**
		Inside Menu	**Outside Menu**	**Objects**	**Move Command**
Transition Counts	**EU 1**	9	8	8	2
	NEU 2	6	6	6	0
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.153	0.136	**0.136**	0.034
	NEU 2	0.089	0.089	**0.089**	0.000
Durations (sec)	**EU 1**	17.715	41.099	6.137	1.305
	NEU 2	18.125	48.980	5.629	0.000
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.301**	**0.699**	**0.104**	0.022
	NEU 2	**0.270**	**0.730**	**0.084**	0.000

Table 64 shows that TC/TCTPI data and D/TCTPI data for Objects on EU 1 are higher than on NEU 2. On the other hand, the D/TCTPI data of EU 1 and NEU 2 for Outside Menu is higher than the data for Inside Menu. It indicates that both EU 1 and NEU 2 were looking at the out of menu area more than menu area in durations.

Table 65 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 65 - Test 2: Time Interval 9 - Gestures

Time Interval 9 (80%-90%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	25	0	3	1	0	3
	NEU 2	10	1	4	1	0	6
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.425**	**0.000**	**0.051**	**0.017**	0.000	**0.051**
	NEU 2	**0.149**	**0.015**	**0.060**	**0.015**	0.000	**0.089**
Durations (sec)	**EU 1**	-	0.000	3.445	0.412	0.000	2.644
	NEU 2	-	1.923	6.971	1.408	0.000	8.671
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.000**	**0.059**	**0.007**	0.000	**0.045**
	NEU 2	-	**0.029**	**0.104**	**0.021**	0.000	**0.129**

As it is seen in the Table 65, C/TCTPI data for Tap gesture for EU 1 is higher than for NEU 2. C/TCTPI data and D/TCTPI data for Zoom Out gesture on EU 1 do not exist, while such data on NEU 2 exist. C/TCTPI data and D/TCTPI data for Zoom In gesture and Drag gesture on EU 1 are smaller than on NEU 2. C/TCTPI data for Select gesture on EU 1 is a little bit higher than on NEU 2, but D/TCTPI data for Select gesture on EU 1 is smaller than on NEU 2. It indicates that EU 1 and NEU 2 were moving around the area and making selections, but EU 1 was more active than NEU 2 in terms of selections.

4.2.10 TIME INTERVAL 10

Time interval 10 includes gaze plots, fixation durations and fixation counts, and tracked area of EU 1 and NEU 2. Figure 34 shows the gaze plots of EU 1 and NEU 2 during Time Interval 10.

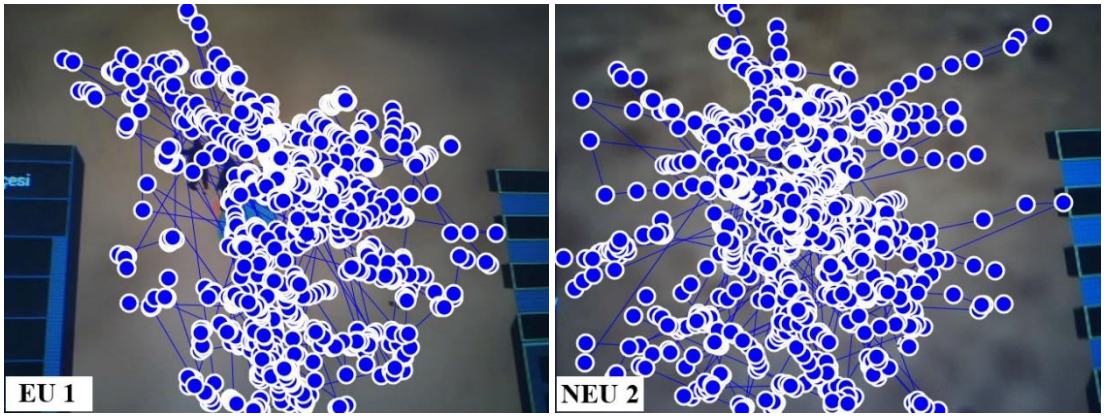


Figure 34 - Test 2: Time Interval 10 - Gaze Plots

Table 66 shows fixation durations and fixation counts of the EU 1 and NEU 2 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 66 - Test 2: Time Interval 10 - Fixation Durations and Fixation Counts

Time Interval 10 (90%-100%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	10.43	12.74	10.07	11.58	44.82
	NEU 2	24.83	6.60	17.03	9.43	57.89
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	0.177	**0.217**	0.171	**0.197**	0.762
	NEU 2	**0.370**	0.098	**0.254**	0.141	0.863
Fixation Count	**EU 1**	313	383	302	348	1346
	NEU 2	745	198	511	283	1737
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	5.322	**6.512**	5.135	**5.917**	22.886
	NEU 2	**11.102**	2.951	**7.615**	4.217	25.885

As it is seen from the Figure 34, the gaze plots of the EU 1 are mostly on right of the screen, while the gaze plots of NEU 2 are mostly on left side of the screen. It is seen in the Table 66 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 2 and AOI 4 are higher than for AOI 1 and AOI 3. However, TFD/TCTPI data and FC/TCTPI data for NEU 2 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on right side of the screen which includes right menu, while NEU 2 was mostly working on left side of the screen which includes left menu.

Table 67 shows counts and durations of EU 1 and NEU 2 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 67 - Test 2: Time Interval 10 - Tracked Area and Command

Time Interval 10 (90%-100%)		Tracked Area			Command
		Inside Menu	Outside Menu	Objects	Move Command
Transition Counts	**EU 1**	9	10	12	1
	NEU 2	13	13	5	0
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.153	0.170	**0.204**	0.017
	NEU 2	0.194	0.194	**0.075**	0.000
Durations (sec)	**EU 1**	29.595	29.222	13.980	0.447
	NEU 2	25.136	41.968	9.800	0.000
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.503**	**0.497**	**0.238**	0.008
	NEU 2	**0.375**	**0.625**	**0.146**	0.000

Table 67 shows that TC/TCTPI data and D/TCTPI data for Objects on EU 1 are higher than on NEU 2. On the other hand, the D/TCTPI data of EU 1 for Outside Menu is almost equal to the data for Inside Menu, while the D/TCTPI data of NEU 2 for Outside Menu is higher than the data for Inside Menu. It indicates that EU 1 was concentrating on menu area and out of menu area with almost equal durations, while NEU 2 was looking at out of menu area more than menu area.

Table 68 shows the counts and durations of gestures performed by each user. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 68 - Test 2: Time Interval 10 - Gestures

Time Interval 10 (90%-100%)		Gestures					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	19	0	2	1	0	12
	NEU 2	17	1	1	10	0	5
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.323**	**0.000**	**0.034**	**0.017**	0.000	**0.204**
	NEU 2	**0.253**	**0.015**	**0.015**	**0.149**	0.000	**0.075**
Durations (sec)	**EU 1**	-	0.000	3.638	0.343	0.000	5.046
	NEU 2	-	0.961	1.717	5.699	0.000	4.223
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.000**	**0.062**	**0.006**	0.000	**0.086**
	NEU 2	-	**0.014**	**0.026**	**0.085**	0.000	**0.063**

As it is seen in the Table 68, C/TCTPI data for Tap gesture for EU 1 is higher than for NEU 2. C/TCTPI data and D/TCTPI data for Zoom Out gesture on EU 1 do not exist, while such data on NEU 2 exist. C/TCTPI data and D/TCTPI data for Zoom In gesture and Drag gesture on EU 1 are higher than on NEU 2. C/TCTPI data and D/TCTPI data for Select gesture on EU 1 is smaller than on NEU 2. It indicates that EU 1 was moving around the area and menus, and making more selections by tapping, while NEU 2 was moving around the area and trying to select objects on the area more.

4.3 COMPARISON OF TEST 1 AND TEST 2

The results of Test 1 and Tests 2 are summarized below for the total task in order. Firstly, the fixation durations and fixation counts for each test in terms of AOIs are indicated. Then, the tracked area during the each test in terms of Menu Inside, Menu Outside and Objects is shown. Finally, the gesture counts for Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture for each test are indicated.

Table 69 shows fixation durations and fixation counts of the EU 1 and NEU 1 for Test 1 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 69 - Test 1: Total Task - Fixation Durations and Fixation Counts

Total Task (0%-100%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	47.21	72.50	37.83	51.17	208.71
	NEU 1	188.96	71.60	152.93	75.93	489.42
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.144**	**0.221**	0.115	**0.156**	0.635
	NEU 1	**0.310**	0.118	**0.251**	0.125	0.804
Fixation Count	**EU 1**	1417	2175	1135	1535	6262
	NEU 1	5669	2148	4588	2278	14683
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**4.313**	**6.620**	3.455	**4.672**	19.060
	NEU 1	**9.311**	3.528	**7.536**	3.741	24.116

It is seen in the Table 69 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1, AOI 2 and AOI 4 are higher than for AOI 3. However, TFD/TCTPI data and FC/TCTPI data for NEU 1 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on upper side of the screen which includes objects and right side of the screen which includes right menu, while NEU 1 was mostly working on left side of the screen which includes left menu and objects.

Table 70 shows fixation durations and fixation counts of the EU 1 and NEU 2 for Test 2 among the AOIs, namely AOI 1, AOI 2, AOI 3, AOI 4 and Full Scene.

Table 70 - Test 2: Total Task - Fixation Durations and Fixation Counts

Total Task (0%-100%)		**AOI 1**	**AOI 2**	**AOI 3**	**AOI 4**	**Full Scene**
Total Fixation Duration (sec)	**EU 1**	140.80	111.90	98.60	77.98	429.28
	NEU 2	258.81	112.17	144.50	80.17	595.65
Total Fixation Duration (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.239**	**0.190**	0.168	0.133	0.730
	NEU 2	**0.386**	0.167	**0.215**	0.119	0.888
Fixation Count	**EU 1**	4224	3358	2958	2340	12880
	NEU 2	7765	3365	4335	2405	17870
Fixation Count / Task Completion Time per Interval (sec)	**EU 1**	**7.182**	**5.710**	5.030	3.979	21.900
	NEU 2	**11.572**	5.015	**6.460**	3.584	26.630

It is seen in the Table 70 that TFD/TCTPI data and FC/TCTPI data of the EU 1 for AOI 1 and AOI 2 are higher than for AOI 3 and AOI 4. However, TFD/TCTPI data and FC/TCTPI data for NEU 2 on AOI 1 and AOI 3 are higher than the data on AOI 2 and AOI 4. This indicates that EU 1 was mostly working on upper side of the screen which includes objects and upper parts of the menus, namely left menu and right menu, while NEU 2 was mostly working on left side of the screen which includes left menu and objects.

For both Test 1 and Test 2, EU 1 was generally working on all over the screen especially on the upper side of the screen, while NEU 1 and NEU 2 was generally working on the left side of the screen.

The places of menus in the software are shown on Figure 35. As it is seen, there are three menu areas which are placed on the right side of the screen, left side of the screen and middle bottom side of the screen.

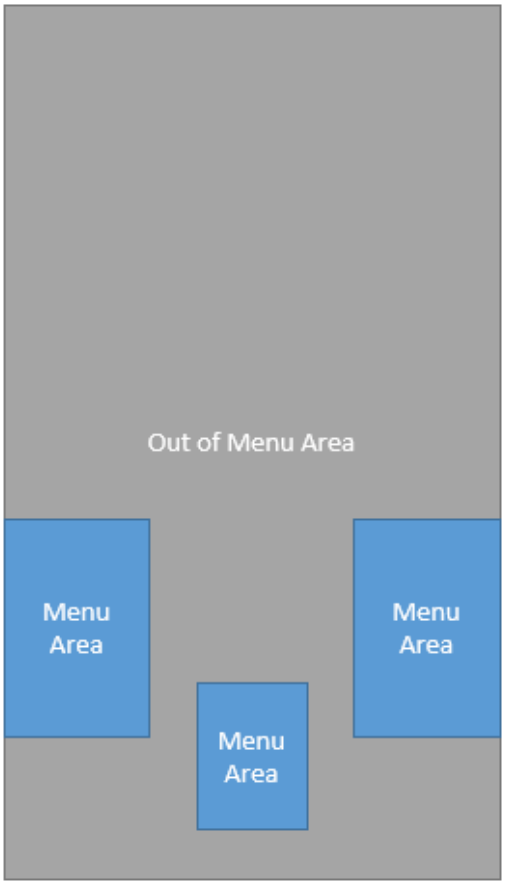


Figure 35 - Menu Area and Out of Menu Area in the Software

The differences between menu inside durations and menu outside durations have similar pattern after the 60% of the task according to Time Intervals (TI) for both EU 1 and NEU 1 for Test 1 (Figure 36). Likewise, the differences between menu inside durations and menu outside durations have similar pattern after the 40% of the task according to Time Intervals (TI) for both EU 1 and NEU 2 for Test 2 (Figure 37). The Y axis values are related to the differences between menu inside durations and menu outside durations. Value 1 means that user is looking on menu inside more than menu outside in durations. Value 2 means that user is looking almost equal durations to menu inside and menu outside. Value 3 means that user is looking on menu outside more than menu inside in durations.

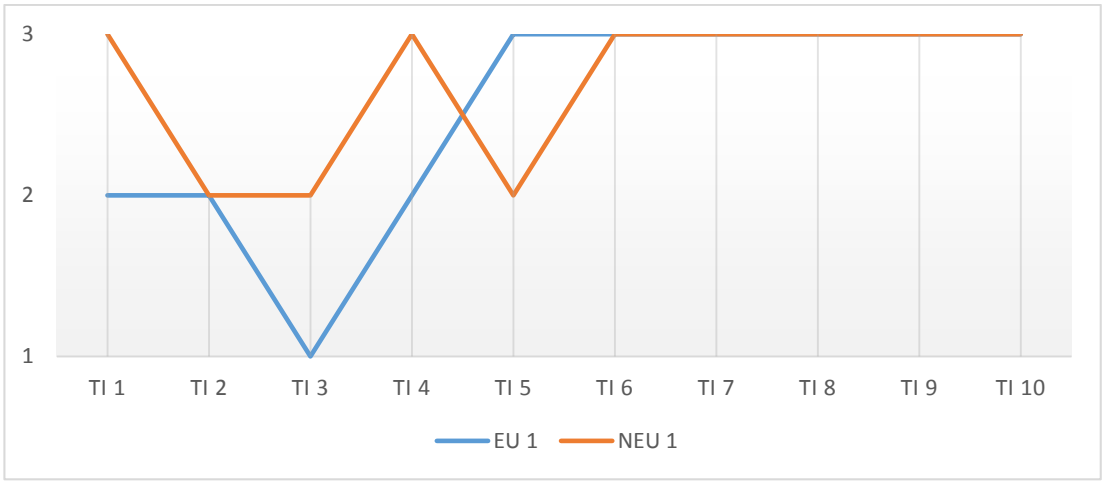


Figure 36 - Test 1: The Working Pattern for EU 1 and NEU 1

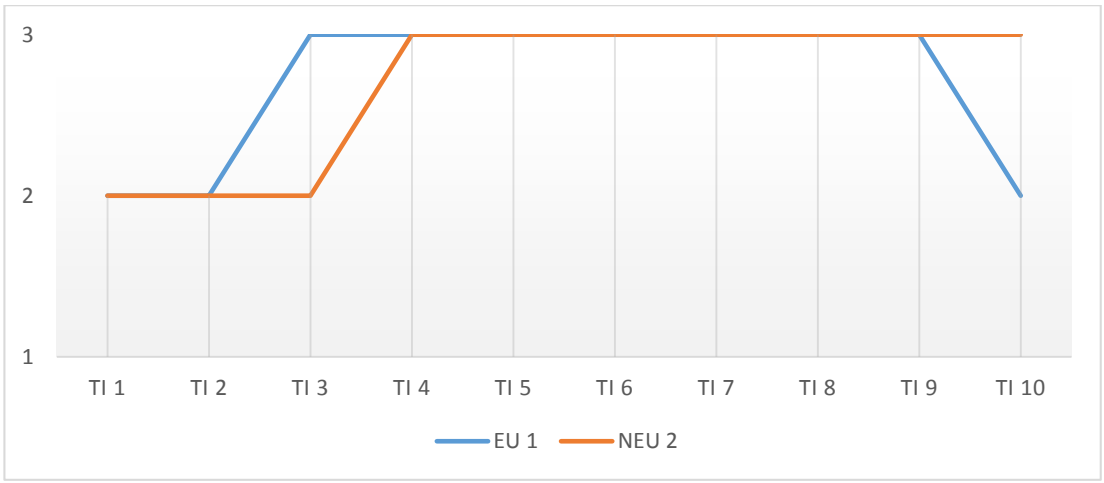


Figure 37 - Test 2: The Working Pattern for EU 1 and NEU 2

Table 71 shows counts and durations of EU 1 and NEU 1 for Test 1 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 71 - Test 1: Total Task - Tracked Area and Command

Total Task (0%-100%)		Tracked Area			Command
		Inside Menu	Outside Menu	Objects	Move Command
Transition Counts	**EU 1**	41	42	28	8
	NEU 1	122	125	66	17
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.125	0.128	**0.085**	0.024
	NEU 1	0.200	0.205	**0.108**	0.028
Durations (sec)	**EU 1**	120.541	208.089	25.167	5.391
	NEU 1	220.473	388.110	58.505	13.631
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.367**	**0.633**	**0.077**	0.016
	NEU 1	**0.362**	**0.637**	**0.096**	0.022

Table 71 shows that TC/TCTPI data and D/TCTPI data for Objects on EU 1 is almost same with on NEU 1. In addition, the D/TCTPI data of both EU 1 and NEU 1 for Outside Menu is higher than the data for Inside Menu. It indicates that both EU 1 and NEU 1 were looking at the out of menu area more than menu area in durations.

Table 72 shows counts and durations of EU 1 and NEU 2 for Test 2 as the tracked area, namely inside menu, outside menu and objects on the area.

Table 72 - Test 2: Total Task - Tracked Area and Command

Total Task (0%-100%)		Tracked Area			Command
		Inside Menu	Outside Menu	Objects	Move Command
Transition Counts	**EU 1**	74	80	87	27
	NEU 2	81	83	72	12
Transition Counts / Task Completion Time per Interval (sec)	**EU 1**	0.126	0.136	**0.148**	0.046
	NEU 2	0.121	0.124	**0.107**	0.018
Durations (sec)	**EU 1**	192.139	395.994	117.384	16.481
	NEU 2	231.610	439.426	78.597	8.171
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	**0.327**	**0.673**	**0.200**	0.028
	NEU 2	**0.345**	**0.655**	**0.117**	0.012

Table 72 shows that TC/TCTPI data and D/TCTPI data for Objects on EU 1 is higher than on NEU 2. In addition, the D/TCTPI data of both EU 1 and NEU 2 for Outside Menu is higher than the data for Inside Menu. It indicates that both EU 1 and NEU 2 were looking at the out of menu area more than menu area in durations.

The results in the Table 71 and Table 72 shows that EU 1, NEU 1 and NEU 2 were looking at the out of menu area more than menu area in durations among the total task for Test 1 and Test 2.

Table 73 shows the counts and durations of gestures performed by each user for Test 1. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 73 - Test 1: Total Task - Gestures

Total Task (0%-100%)		**Gestures**					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	88	8	11	8	1	44
	NEU 1	149	21	5	2	3	54
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.268**	**0.024**	**0.033**	**0.024**	**0.003**	**0.134**
	NEU 1	**0.245**	**0.034**	**0.008**	**0.003**	**0.005**	**0.089**
Durations (sec)	**EU 1**	-	10.367	14.453	2.747	0.515	24.411
	NEU 1	-	50.616	9.992	1.340	4.910	72.310
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.032**	**0.044**	**0.008**	**0.002**	**0.074**
	NEU 1	-	**0.083**	**0.016**	**0.002**	**0.008**	**0.119**

As it is seen in the Table 73, C/TCTPI data for Tap gesture on EU 1 is a little bit higher than on NEU 1. C/TCTPI data and D/TCTPI data for Zoom Out gesture and Rotate gesture for EU 1 are smaller than for NEU 1. However, C/TCTPI data and D/TCTPI data for Zoom In gesture, Select gesture and Drag gesture for EU 1 are higher than for NEU 1.

Table 74 shows the counts and durations of gestures performed by each user for Test 2. These gestures are Tap gesture, Zoom Out gesture, Zoom In gesture, Select gesture, Rotate gesture and Drag gesture.

Table 74 - Test 2: Total Task - Gestures

Total Task (0%-100%)		**Gestures**					
		Tap	**Zoom Out**	**Zoom In**	**Select**	**Rotate**	**Drag**
Counts	**EU 1**	188	19	21	14	0	79
	NEU 2	203	19	16	16	1	73
Counts / Task Completion Time per Interval (sec)	**EU 1**	**0.320**	**0.032**	**0.036**	**0.024**	0.000	**0.134**
	NEU 2	**0.303**	**0.028**	**0.024**	**0.024**	0.001	**0.109**
Durations (sec)	**EU 1**	-	26.471	26.812	5.630	0.000	64.544
	NEU 2	-	35.981	29.012	8.858	1.236	86.894
Durations (sec) / Task Completion Time per Interval (sec)	**EU 1**	-	**0.045**	**0.046**	**0.010**	0.000	**0.110**
	NEU 2	-	**0.054**	**0.043**	**0.013**	0.002	**0.129**

As it is seen in the Table 74, C/TCTPI data for Tap gesture on EU 1 is a little bit higher than on NEU 2. C/TCTPI data for Zoom Out gesture and Drag gesture on EU 1 is higher than on NEU 2, but D/TCTPI data for Zoom Out gesture and Drag gesture on EU 1 is smaller than on NEU 2. C/TCTPI data and D/TCTPI data for Zoom In gesture for EU 1 are higher than for NEU 2. C/TCTPI data for Select gesture on EU 1 is equal to the data on NEU 2, but D/TCTPI data for Select gesture on EU 1 is smaller than on NEU 2. C/TCTPI data and D/TCTPI data for Rotate gesture on EU 1 do not exist, while such data on NEU 2 exist.

As it is seen in the Figure 38, EU 1 was moving around the area more than NEU 1 and making selections a little bit more than NEU 1 in counts in Test 1. Likewise, in Test 2 (Figure 39), EU 1 was moving around the area more than NEU 2 and making selections more than NEU 2 in counts.

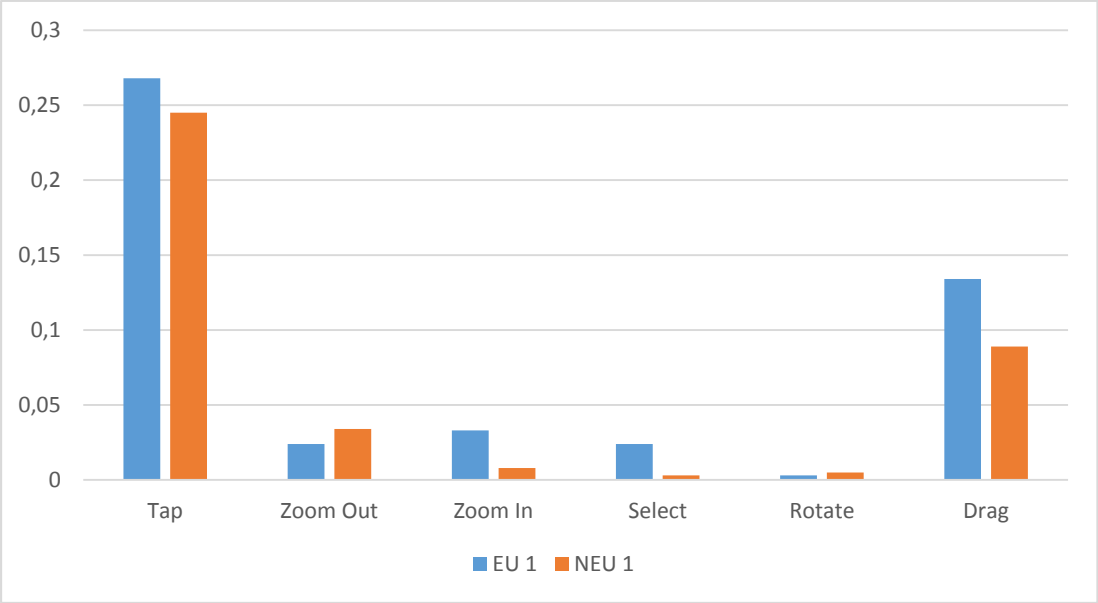


Figure 38 - Test 1: Gesture Counts for EU 1 and NEU 1

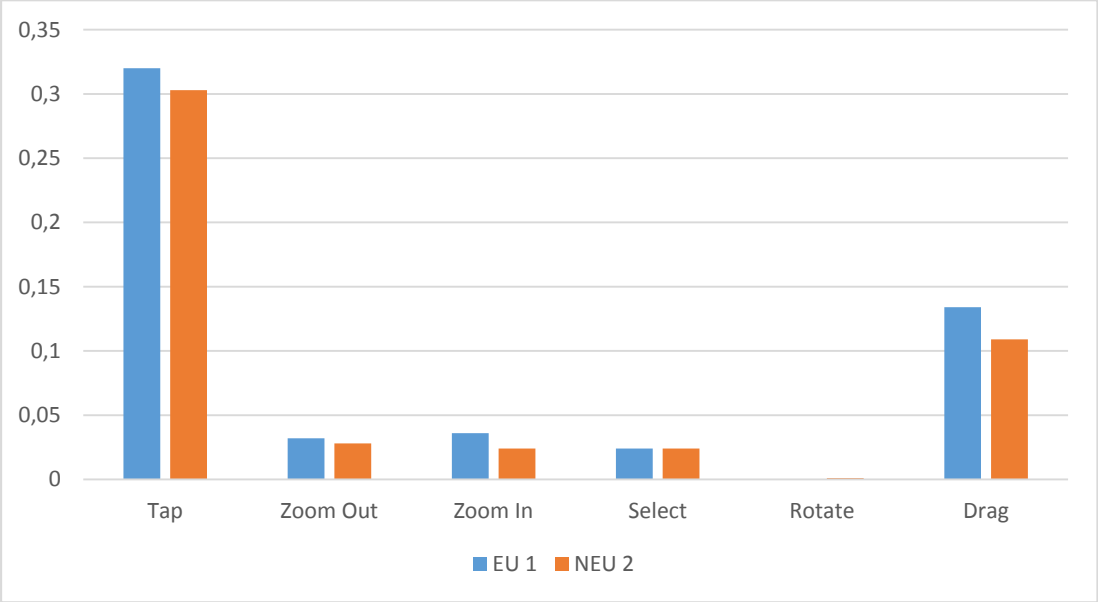


Figure 39 - Test 2: Gesture Counts for EU 1 and NEU 2

4.4 RESULTS OF INTERVIEWS

For this study, 1 Expert User (EU) and 3 Non-Expert Users (NEU) were interviewed about their experience during the tests.

Table 75 - Interview Questions

Original Interview Question	**Translation of Interview Question**
Uygulamada zorlandığınız kısımlar oldu mu? Hangi kısımda zorlandınız? Nasıl çözülebilir?	Is there any part of the application which is difficult for you? How can it be solved?
Ekran boyutunun avantajları ve dezavantajları nelerdir?	What are the advantages and disadvantages of the screen size?
Alışık olduğunuzdan farklı dokunmatik hareketler (Gesture) var mıydı? Varsa ne gibi etkileri oldu? Kullanmakta zorlandınız mı? Gesture önerileriniz var mıdır?	Is there any gesture different from gestures that you are familiar with? If there is, what are the effects of it? Did you have difficulty to use it? Do you have any gesture suggestion?
Kullanımı etkileyen faktörler konusunda önerileriniz var mı? Varsa bunlar nelerdir?	Do you have any suggestion about the factors which affect usage? If you have, what are they?

Interview questions listed in the Table 75 consist of questions about the research questions of this study.

Table 76 - Research Questions and Main Codes

Research Question	**Main Code**	
What do the usability factors influence participants on using very large multi touch displays?	Challenges	Device
		Application
	Advantages	Device
		Application
	Disadvantages	Device
		Application
What design suggestions can be given for very large multi touch displays?	Suggestions	Device
		Application

For the analysis of the interviews, main codes and sub-themes were generated from interviews. Each main code was interpreted into two headings, namely device and application. The main codes are presented in Table 76 for each research question.

In the sections below, each research question was examined in detail. Each sub-theme with its quotations of participants was given under each main code.

4.4.1 RESEARCH QUESTION 1

The related research question is: “What do the usability factors influence participants on using very large multi touch displays?”

Table 77 - Research Question 1: Main Codes and Sub-Themes

Main Code		**Sub-theme**
Challenges	Device	Transferring previous habits
	Application	Command errors
		Object selection
		Unfamiliar to software
		Notifications problem
Advantages	Device	Easy to select objects
		Easy to see the area
		Easy to see the objects
		Using with two hands
	Application	Tools menu easing to use
		Close to real life
		Easy to adapt gestures
		Satisfied user
		Easy to move camera to see the area
		Highlight on selections
		Extra gesture option to ease the use of large multi touch display
		Making possible to give command for moving objects
Disadvantages	Device	Hard to use upper side of the screen
		Need to calibrate the screens
	Application	No window to follow moving objects
		Gesture problem

The main codes and sub-themes are given in Table 77 for Research Question 1. For each main code and its sub-themes, the quotations of the participants were given below.

4.5.1.1 CHALLENGES

In order to identify the challenges about large multi touch displays, interviews were conducted with 1 EU and 3 NEU. The challenges were interpreted under two headings, namely device and application.

DEVICE

During the analysis of the interviews, challenges about device were listed under the sub-theme, transferring previous habits.

Transferring Previous Habits

Users tried to transfer previous habits from their experiences with smart devices such as smart phones, tablet PCs, iPhones or iPads. Therefore, it was easy to adapt to some of gestures for users with the help of the familiarity from smart devices like Tap gesture, Zoom Out gesture, Zoom In gesture and Rotate gesture.

EU 1 supported this by saying: "Of course, it is difficult to play on such a big size screen. The difficulty is because of that other fingers enter the sensor area and it causes for giving a different mission from the intended mission, while the device normally has to understand just two fingers."

> *"Böyle büyük bir ekranda tek el oynamak tabi ki zor oluyor. Şu açıdan zor oluyor normalde iki parmağını algılaması gerekirken bu parmak hareketini yaparken diğer parmaklar da sensör alanına girdiği için ister istemez senin vermek istediğin görevden daha çok farklı görevlere de kayma ihtimali oluyor." [EU 1]*

EU 1 also stated: "Rotate gesture is the thing that confuses the mind of users. Except from it, the other gestures are easier for smart phone users. However, I concentrated on Rotate gesture, Zoom In gesture and Zoom Out gesture here, because they are more complex."

> *"Rotateler daha çok kafa karıştıran şeyler oluyor. Onun haricinde diğer seçimler hani dokunmatik ekran kullananlar telefon kullananlar için hani rahat şeyler ama burada rotate ve zoom in zoom outlar biraz daha complex olduğu için daha çok onlar üzerinde yoğunlaştım." [EU 1]*

APPLICATION

The challenges about application were interpreted under four sub-theme, namely command errors, object selection, unfamiliar to software and notifications problem.

Command Errors

During the experiences of users with the large multi touch display for this study, they faced with errors or problems while giving commands. For example, there can be need for default value option for move command.

NEU 1 supported this by saying: “While giving command for vehicles and characters, there is a need to select the speed of the object as a second stage.”

> *“Araçlara veya işte karakterlere ilerleme komutu verirken ikinci bir aşama olarak hızını seçip ondan sonra vermek gerekiyor.” [NEU 1]*

In addition, NEU 1 stated: “My vehicle did not move because of a reason. Therefore, I selected it again and moved it.”

> *“Aracım ilerlemedi bir sebepten dolayı tekrar seçtim tekrar ilerlettim.” [NEU 1]*

Besides, NEU 3 expressed: “I cannot give command for sending patrols because of an error.”

> *“Oluşan bir hata nedeniyle devriye at komutunu veremiyorum.” [NEU 3]*

Object Selection

While selecting objects from the application, users faced with problems related to this selection. The application area is just like real world. When they zoomed out too much, the objects were seemed very tiny. Therefore, it was hard for users to select objects while zooming out too much.

EU 1 supported this by saying: “When I zoom out the camera too much or I set the camera viewpoint to 500-600 meters instead of 25-30 meters, this makes it difficult to see and select the intended target.”

> *“Kamera pozisyonunu bayağı bir yükseğe taşıdığımda veya kameranın bakış açısını 25-30 metre değil de 500-600 metrede baktığımda gördüğüm hedef veya gördüğüm nesne seçmek istediğim nesne zorlaşıyor tabi.” [EU 1]*

NEU 3 also pointed out: “While using the application, I slogged on selecting small objects from wide view as only I saw. The solution for this is related to my usage. I had to select after zooming in. The object is small and I think that there is nothing to do about this.”

> *“Uygulamayı kullanırken sadece gördüğüm kadarıyla burada çok yukarda olduğumda küçük nesneleri seçmekte zorlandım. Bunun çözümü zaten kullanımla alakalı bir şey aslında, kendim yaklaşıp seçmeliydim. Nesne küçük, bunun için yapılabilecek bir şey olmadığını düşünüyorum.” [NEU 3]*

Unfamiliar to Software

Some of users were unfamiliar to application, so they were not able to use all the gestures and tools provided by the application effectively.

NEU 1 expressed: “However, I understand that I have to put soldiers on vehicle when my other friend by my side said that there is no smugglers there.”

> *“Ancak yan tarafımdaki diğer arkadaşın kaçakçıların orada olmadığını söyleyince tekrar bindirmem gerekeceğini anladım.” [NEU 1]*

Researcher field notes also supported this by indicating: “Some of the users are not fully aware of the all available gestures in the application and they prefer not to use while it eases their works. I think the reason for not using such gestures is that such gestures are not one of the standard gestures.”

> *“Bazı kullanıcılar uygulamanın sunduğu gestureların tümüne hakim değil ve işleri kolaylaştırabilecekken kullanmıyorlar. Standart kullanılan gesturelardan olmadıklarından dolayı kullanmayı tercih etmediklerini düşünüyorum.” [Researcher Field Note]*

Notifications Problem

During the experiences of users, it was recorded that some of the notifications were appearing under the eye sight of the users. Therefore, it was hard to realize the notifications for users until getting used to.

Researcher field notes supported this by stating: “Some of the notifications and choices are under the eyesight of the users. Recognizing the notifications and choices changes with the expertise of the users on application. Expert user knows where the application gives notifications or choices because of his expertise on the application. However, non-expert users may not see the notifications or choices, and try to figure out the intended error for given command.”

> *“Bazı uyarılar ya da seçenekler de kullanıcının bakış açısının altında kalıyor. Kullanıcının uyarı veya seçeneği fark etmesi uygulamaya olan alışkanlığı ile değişiyor. Uygulamayı sürekli kullanan kişi alışık olduğundan dolayı nerede uyarı ya da seçenek çıkacağını biliyor ve ona göre hareket ediyor. Fakat uygulamayı sıklıkla kullanmayan kişi uyarı veya seçeneği görmeyip verdiği komutun hatalı olduğunu düşünerek sorun giderme çabalarına giriyor.” [Researcher Field Note]*

4.5.1.2 ADVANTAGES

In order to identify the advantages about large multi touch displays, interviews were conducted with 1 EU and 3 NEU. The advantages were interpreted under two headings, namely device and application.

DEVICE

The advantages about device were interpreted under four sub-theme, namely easy to select objects, easy to see the area, easy to see the objects and using with two hands.

Easy to Select Objects

It was easy to select objects with the help of large multi touch display. Users took the advantage of selecting easily by using Tap gesture and Select gesture.

NEU 2 supported this by saying: “While using the touch screen for selections, I am more comfortable.”

> *“Seçimlerde dokunmatik ekranda daha rahat edebiliyorum kullanırken.” [NEU 2]*

Easy to See the Area

It was easy to explore the area which includes objects as the advantage of use large display size. Users were managing the objects, namely soldiers and vehicles easily by using Zoom out gesture, Zoom In gesture and Drag gesture.

EU 1 supported this by saying: "It provides clearer sight on the larger screen, even if I zoom out instead of zoom in on object."

> *"Daha geniş ekranda dediğim gibi bir nesneyi büyütmek yerine ekranı büyüttüğünde nesneye ne kadar yukarıdan bakarsam bakayım nesne daha açık ve net görünme imkanı sağlıyor." [EU 1]*

In addition, NEU 1 pointed out: "I think the size of the screen is good because recognizing the moves and scenario that have wide range would be difficult if the size of the screen was smaller. I would have to move the area more often. Therefore, I think that I have control on the more events with using less gestures."

> *"Ekran boyutu bence iyi, çünkü daha küçük bir ekran olsaydı hareketleri ve işte daha geniş alan olduğundan dolayı senaryonun tespit edilmesi daha zor olurdu. Daha sık hareket ettirmem gerekecekti. Böylece daha az hareketle daha çok olaya hakim olduğumu düşünüyorum." [NEU 1]*

Besides, NEU 3 stated: "In fact, the large screen size is an advantage, because it provides a comfortable sight on the area of responsibility and on the other areas."

> *"Ekran boyutu büyük olması aslında avantajlı tüm araziyi kendi sorumluluk alanımı diğer alanları rahat bir şekilde görebilmemi sağlıyor." [NEU 3]*

Easy to See the Objects

It was easy to follow and manage the objects with the help of large multi touch display. It was easy to follow objects by moving camera.

EU 1 supported this by saying: "Like I said, the large screen size provides a lot of advantages like seeing objects more afar, seeing objects better and showing objects bigger."

> *"Büyük ekran dediğim gibi hatta avantajı çok daha fazla işte nesneleri daha uzaktan görebilmek için daha iyi görebilmek için daha büyük gösterebilmek için bayağı olanak sağlıyor." [EU 1]*

Using with Two Hands

Some users were used to use touch devices with one hand, but there can be necessary to use with two hands for large multi touch displays. It was easy for users to act gestures by using two hands.

EU 1 expressed: "But, it provides more comfortable usage, when it is used with one finger from each hand. This prevents the entering the other fingers into the area of sensor. Therefore, you can set intended target or give intended command more clearly and more easily."

"Ama bunu iki el oynayıp da işte iki parmak kullandığınız zaman daha rahat kullanma imkanı sağlıyor. O da diğer parmakların sensör alanına girmesini engelliyorsunuz ve böylece işte vermek istediğiniz hedefi vermek istediğiniz görevi çok daha net ve kolay bir şekilde verebiliyorsunuz. Daha bir kolaylık sağlıyor." [EU 1]

APPLICATION

The advantages about application were interpreted under eight sub-theme, namely tools menu ease to use, close to real life, easy to adapt gestures, satisfied user, easy to move camera to see the area, highlight on selections, extra gesture option to ease the use of large multi touch display and making possible to give command for moving objects.

Tools Menu Easing to Use

Tools menu of the application provided easiness during the experience of users like checking the events, navigating around the area in which an event was occurred, and enabling the symbols of objects or optional equipment.

EU 1 supported this by saying: "I enabled all the things of the layers as I want to see."

"Ekranda görmek istediğim şekilde katmanların hepsinin şeylerini açtım." [EU 1]

Also, NEU 1 stated: "I enabled the shape layer in order to see the line of demarcation and the other information."

"Sınır çizgilerini ve diğer bilgileri görebilmek için şekil katmanını açtım." [NEU 1]

In addition, NEU 2 pointed out: "I am reviewing about what there are, what is missing, and what is extra. Then, I am enabling shape layer and unit layer from tools menu in order to see the paths, see the symbols of soldiers. After that, I am enabling the scale option and compass in order to understand where I am, what my direction is, and what time it is."

"Gözden geçiriyorum. Neler var? Neler eksik? Neler fazla? Daha sonra araçlar butonundan şekil katmanını, birlik katmanını açıyorum ki pathleri görebileyim. Askerlerin sembollerini görebileyim. Daha sonra ölçek birimini açıyorum. Pusulayı açıyorum. Neredeyim? Yönüm neresi? Saatim kaç?" [NEU 2]

Besides, NEU 3 stated: "The information window is an advantage for me, because it provides an easy way to see and move to the area of the event. Also, unit tree is the one of the advantages for easing my usage."

"Ya benim için bilgi penceresi mesela olumlu olay penceresi pardon olumlu etkileyen bir faktör. Çünkü oradan olayları görüp olayın olduğu yere rahatça gidebilmemi sağlıyor. Yine birlik ağacı da rahat kullanmamı sağlayan faktörlerden biridir." [NEU 3]

Close to Real Life

The application environment was very close to real life in terms of the size of the objects, commands and events.

NEU 2 supported this by saying: “The smugglers can be anywhere because it is not possible to their symbols. Therefore, I am alerting all of my guardhouses.”

> *“Kaçakçılarımın sembolünü görmediğim için her yere gidebilirler. O yüzden bütün karakolları alarma geçiriyorum.” [NEU 2]*

Easy to Adapt Gestures

It was easy for users to adapt gestures because of their previous experiences with smart devices. They easily used gestures like Tap gesture, Zoom Out gesture and Zoom In gesture.

NEU 2 supported this by saying: “I used Tap gesture, Zoom Out gesture and Zoom In gesture before, so it provides easiness.”

> *“Pen, zoom in, zoom out hareketlerini kullandım daha önce. O yüzden kolaylık sağladı.” [NEU 2]*

In addition, NEU 3 stated: “There was no gesture different than the gestures that I am familiar with, because we used the gestures that we are familiar from our Android phones here.”

> *“Alışık olduğumdan farklı bir gesture yoktu aslında. Çünkü normal Android telefonlarımızda dokunmatik telefonlarımızda kullandığımız gestureları kullandık burada da.” [NEU 3]*

Satisfied User

Users were satisfied about the capabilities of the device and application. They evaluated their experiences with the application as satisfactory.

EU 1 supported this by saying: “There is no specific gesture to say that it has to be in the application, because we used almost all of the keywords and gestures here. Except from them, there is no gesture to say that it has to be in the application.”

> *“Şu anda aklıma gelmiyor açıkçası hani öle specific ki burada birçok keywordleri kullanmış olmamız lazım hani birçok şeyi kullandık durumu. Hani onun haricinde olsun dediğim açıkçası çok fazla bir şey yok.” [EU 1]*

Also, NEU 2 stated: “There is no gesture to suggest for the application because existing gestures are from the gestures which we are familiar from our daily lives. Therefore, using existing gestures is easier way.”

> *“Yok, gayet güzel yani günlük hayatta kullandığımız hareketler olduğu için daha farklı bir hareket olsa keşke demiyoruz. Çünkü zaten alıştığımız hareketler. O yüzden onları kullanmak daha kolay olur.” [NEU 2]*

In addition, NEU 3 pointed out: “I do not have any gesture suggestion for this application.”

> *“Gesture önerim yok açıkçası.” [NEU 3]*

Easy to Move Camera to See the Area

It was easy for users to navigate around the area by moving the camera position in the application via Drag gesture. It simplified the management of the task for them.

EU 1 supported this by saying: "In this area, I am trying to find my target which I want to follow. I set the camera position to see both my vehicle and the target."

> *"Bu alanda takip etmek istediğim hedefimi bulmaya çalışıyorum. Hem aracımı hem de hedefi aynı anda görmek için kamera pozisyonumu da ayarladım." [EU 1]*

In addition, EU 1 indicated: "Now, I am trying to move camera position in pursuance of my demand. Then, I will see more clearly."

> *"Şu an kamera pozisyonlarını kendime uygun hareket ettirmeye çalışıyorum. Daha net görebileceğim." [EU 1]*

Highlight on Selections

While using the application, the selections of the users were highlighting by the application. These feedback from the application was providing clearer sight for users about selected objects like soldiers and vehicles.

EU 1 supported this by saying: "When I make my selection, it is showed up with a highlight."

> *"Zaten seçimim de belli oluyor böyle yeşil highlightı çıkıyor onların." [EU 1]*

Extra Gesture Option to Ease the Use of Large Multi Touch Display

There was extra gesture option to ease the use of large multi touch display for Zoom In gesture and Zoom Out gesture. The option is for speeding up or slowing down the zoom action by moving the fingers up or down on the screen after starting the Zoom Out gesture or Zoom In gesture. It provides user to zoom in and zoom out quickly or slowly.

EU 1 supported this by saying: "Normally, when we set the zoom in position and angle, the camera starts to get closer slowly. It gets closer slowly on the selected area. If I want to zoom in more quickly, I am moving my hands up or down. Then, the camera zooms in more quickly without changing the angle of selection. Or, I am setting the adjustment of it by myself."

> *"Şimdi normalde zoom in yaparken o zoom in şeyini belirlediğimiz anda açısını belirlediğimiz anda kamera yavaş yavaş yaklaşmaya başlıyor. Benim o seçtiğim aralıkta yavaş yavaş yaklaşıyor. Eğer daha hızlı yaklaşmasını istiyorsam bir el hareki yukarı kaydırdığımda aynı açıda açı sabit kalmak suretiyle yukarı kaydırdığımda veya aşağı kaydırdığımda zoom ini daha hızlı yapıyor. Veya onun ayarını kendim şey yapıyorum." [EU 1]*

Besides, EU 1 stated: "As I stated, Rotate gesture, Zoom In gesture and Zoom Out gesture are a little bit different than standard gestures. It was not difficult to use them. On the contrary, it was an advantage for me. For instance, I used Zoom In gesture and Zoom Out gesture as I wanted to get close with certain speed. Of course, while using Zoom In gesture or Zoom Out

gesture, I moved my hands up or down too for moving the camera slower or faster. It was an advantage for me. I could set the speed of the Zoom In gesture and Zoom Out gesture."

> *"Şöyle söyleyeyim dediğim gibi rotate ve zoom in zoom outlarda birazcık farklılıklar vardı. Zorlanmadım açıkçası hani benim için bir avantaj oldu. İstediğim oranda zoom in de örnek verebilirsek, zoom inde veya zoom outda belli bir harekette belli bir şeyde hızla mesela şeyle yaklaşmaya başladım. Tabi ben onu diğer el hareketlerimle işte yukarı aşağı taşıyarak daha hızlı zoom in veya daha yavaş zoom in zoom out yapmayı sağladım. Bu da benim için bir avantajdı. Hani istediğim oranda büyültüp istediğim oranda küçültebiliyorum." [EU 1]*

Making Possible to Give Command for Moving Objects

It was easy to give command for moving objects with the help of the screen size. For example, it was easy to follow objects on the screen after giving move command for it. While it is within the display limits, users can select and give another command on moving objects. Thanks to large display size, objects can be followed through wide range of area.

EU 1 supported this by saying: "Now, I am trying to give command on a moving object and to set it as target. I am setting it by using touch because the object maintains his movement continuously."

> *"Şu an hareket eden bir nesne üzerine görev vermeye çalışıyorum hedef olarak belirlemeye çalışıyorum. O devamlı hareket ettiği için o hareket anında dokunmatikle onu algılamasını sağlıyorum." [EU 1]*

4.5.1.3 DISADVANTAGES

In order to identify the disadvantages about large multi touch displays, interviews were conducted with 1 EU and 3 NEU. The disadvantages were interpreted under two headings, namely device and application.

DEVICE

The disadvantages about device were interpreted under two sub-theme, namely hard to use upper side of the screen and need to calibrate the screens.

Hard to Use Upper Side of the Screen

Users were working on the device by sitting in front of it. Therefore, it was hard to use and upper side of the screen. Users had problems about reaching the upper side of the screen and realizing the activities which occurred there.

NEU 2 supported this by saying: "The disadvantage is the size of the screen. It is too big and it can be difficult to reach upper side of the screen. I think this is disadvantage. We have to play the game on bottom side of the screen. We cannot play by using all of the screen."

> *"Dezavantajı da ekran boyutu çok büyük en üst kısımlara ulaşmakta zorluk çekebiliyoruz. Dezavantajı da bu olduğunu düşünüyorum. Daha çok yani oyunu daha çok daha aşağıda oynamak zorunda kalıyoruz. Tüm ekranı kullanarak oynayamıyoruz." [NEU 2]*

In addition, NEU 3 pointed out: "Sometimes, we cannot use upper side of the screen. We cannot use upper side of the screen when we work by sitting."

> *"Bazen tabi ekranın üst kısımlarını kullanamıyor olabiliyoruz. Oturarak çalıştığımızda ekranın en üst kısımlarını kullanmıyor oluyoruz." [NEU 3]*

Also, researcher field notes supported this by stating: "The users are using the device by sitting, so the upper side of the screen can be useless."

> *"Kullanıcılar cihazı sandalyede oturarak kullanıyorlar, bundan dolayı ekranın üst kısımlar kullanışsız kalıyor. [Researcher Field Note]*

Need to Calibrate the Screens

The device requires calibration very often because of its size and its precision. Users had to calibrate it before starting to use it.

EU 1 supported this by saying: "The disadvantage is that the device needs calibration frequently. It can be affected from the light or any other things. This makes the usage a little bit difficult."

> *"Dezavantajı da sık sık kalibre etmemiz gerekiyor. Veya işte ışıktan veya herhangi başka bir şeyden çok daha algılayabiliyor kendini. Bu da kullanımı biraz zorlaştırıyor." [EU 1]*

APPLICATION

The disadvantages about application were interpreted under two sub-theme, namely no window to follow moving objects and gesture problem.

No Window to Follow Moving Objects

There is a need for a window to follow moving objects on the application like soldiers and vehicles, because users can forget the objects on which they give move command.

NEU 2 supported this by saying: "Only, finding the units which are in the vehicle could be difficult. Or, finding the moving vehicles was difficult."

> *"Sadece belki araca binmiş birlikleri bulmakta zorlandım. Veya hareket ettirdiğim aracımı bulmakta zorlandım." [NEU 2]*

Gesture Problem

Some of users were not familiar with some standard gestures like Rotate gesture, so they have difficulties to understand the usage of such gesture.

NEU 2 supported this by saying: "I have never used Rotate gesture before. I mean that we are fixing one of our fingers and rotating another finger through right or left. I do not remember that I used this gesture on my existing devices."

"Yani daha önce kullanmadığım hareket ekranı çevirmek. Yani bir parmağımızı ekrana sabitliyoruz ve diğer parmağımızı da sağa sola çeviriyoruz. Bu hareketi ben normal cihazlarımda kullandığımı hatırlamıyorum." [NEU 2]

4.4.2 RESEARCH QUESTION 2

What design suggestions can be given for very large multi touch displays?

Table 78 - Research Question 2: Main Codes and Sub-Themes

Main Code		**Sub-theme**
Suggestions	Device	Touch screen problem
	Application	Need for a window to follow moving objects
		Need for enhancement about gesture sensitivity
		Need for default value option for move command

The main codes and sub-themes are given in Table 78 for Research Question 2. For each main code and its sub-themes, the quotations of the participants were given below.

4.5.2.1 SUGGESTIONS

In order to identify the suggestions about large multi touch displays, interviews were conducted with 1 EU and 3 NEU. The suggestions were interpreted under two headings, namely device and application.

DEVICE

During the analysis of the interviews, suggestions about device were listed under the sub-theme, touch screen problem.

Touch Screen Problem

Users had problems about the frame type touch screen, while acting gestures. Their other fingers were entering the touch area. The system was sensing this as touch gesture and acting according to the gesture definitions of the system. This issue caused to act unintended gestures by users, so there is a need for enhancements on the system.

EU 1 supported this by saying: "Entering of the other fingers into touch sensor area can be problem. The solution for this can be using the pressure-sensing touch screen in the device instead of using the frame type (IR) touch screen. I think that it can be difficult for big systems like this device. I mean this kind of enhancements can be done."

"Diğer parmakların sensör alanına girmesi bu biraz şey oluyor o da çözüm olarak sensörün çerçeve şeklinde değil de işte dokunmatik basınç şeklinde ekrana gömülmesi olur. Bu büyük sistemlerde de biraz zor olduğunu düşünüyorum. Yani o anlamda geliştirilebilir." [EU 1]

APPLICATION

During the analysis of the interviews, suggestions about application were listed under four sub-theme, namely need for a window to follow moving objects, need for enhancement about gesture sensitivity and need for default value option for move command.

Need for a Window to Follow Moving Objects

There is a need for a window to follow objects like soldiers and vehicles on which users give move command. When they give move command for more than one object, they can forget that which object will move through which direction. They have to search for objects by moving the camera in the current situation. Therefore, there is a need for an enhancement like window to follow moving objects.

NEU 2 supported this by saying: "Maybe, if there is an indicator on my moving vehicle, I can be more comfortable. I mean that there can be an indicator. There can be information on the information window about which vehicles are moving or who are inside the vehicle."

> *"Hani belki hareket ettirdiğim araçta bir belirteç olsaydı daha rahat edebilirdim. Yani bir belirteç olabilir. Hani hareket ediyor şu an hareket ediyor veya şu an içinde şu kişiler var diye bilgi olabilir bilgi penceresinde onlar yok sanırım onlar olabilir." [NEU 2]*

In addition, EU 3 stated: "the moving objects could be shown on somewhere in the application. For example, there could be feedback like this object is moving now, and it is performing this command. We can call them as active objects. There can be a window to show active units or active people. Therefore, it could provide better sight for me."

> *"Hareket halindeki bir nesnemi bir yerde gösteriyor olabilirdik mesela hani bu nesne şu an hareket halinde ve şu görevi yapıyor gibi bir geri dönüş olabilirdi. Onun haricinde görev yapan nesnelerin diyebilirim ya da buna. Görev yapan birliklerimi ya da insanlarımı gösteren bir kısım olabilirdi. Böylece onlara rahat gidebilmemi sağlardı." [NEU 3]*

Besides, researcher field notes supported this by stating: "Users are trying to follow active objects by enabling the symbols from tools menu and looking the area by zooming out because there is no window to follow active objects. As a result, the completion duration of the task was affected from this."

> *"Hareket halindeki objeleri takip edebilecekleri bir pencere olmadığından dolayı hareket halindeki araçları seçenekler menüsünden sembolleri açarak çalışma alanlarına uzaktan bakarak takip etmeye çalışıyorlar. Bu da görevin tamamlanma sürecini etkiliyor." [Researcher Field Note]*

Need for Enhancement about Gesture Sensitivity

There is a need for enhancement about gesture sensitivity of the application in order to prevent unintended gesture recognition. Until completing the current gesture, application should not recognize and act for another gesture.

EU 1 supported this by saying: “My suggestion is that after I started to perform a gesture, the other fingers which can enter accidentally inside the sensor area should not be sensed by the application.”

> *“İşte dediğim gibi ikinci bir elin girmesi işte ben bir işlemi yaparken başka bir şey sensör alanına girdiğinde artık benim eskiyi algılayıp onu hiç dikkate almaması gibi bir önerim olabilir.” [EU 1]*

Need for Default Value Option for Move Command

While giving move command, users have to choose some options each time. There can be provided a default value without forcing the users to select any option. The options for the move command can be optional.

NEU 1 supported this by saying: “For move command, the default value for the speed should be applied automatically without tapping on any button. However, if you want to set different speed value, then you should choose. Maybe, this feature can be improved.”

> *“Bu noktada belki o aşama atlanabilir veya hani ortalama hız seçilecekse hiç tamama basmaya gerek kalmadan komut direk verildiğinde yani önceden tanımlanan değer ne ise o geçerli oluyor olabilir. Ama ekstra hız ayarlaması yapmak istersen o zaman seçiyor olabilirim. Belki bu geliştirilmesi gereken bir yöndür.” [NEU 1]*

4.4.3 SUMMARY OF THE INTERVIEW RESULTS

The results of the interviews are summarized below.

- Users tried to transfer previous habits from smart devices. Therefore, it was easy to adapt gestures for users.
- Users faced with command errors while giving commands. In addition, there can be need for default value option for move command.
- Users faced with problems related to object selection.
- Some user was unfamiliar to software, so they were not able to use all the gestures provided by the application effectively.
- Some of the notifications were appearing on out of the users’ eye sight, so they had problems to realize the notifications until getting used to.
- For users, it was easy to select objects, to see the area, to see the objects, and to move camera to see the area.
- Some users were used to use touch devices with one hand, but it was easier for them to use large multi touch display with two hands.
- Tools menu provided easiness during the experience of users like checking the events and navigating around the area.
- The application environment was very close to real life such as the size of the objects, commands and events.
- Users were satisfied about the capabilities of the device and application.
- While using the application, the selections of the users were highlighted by the application and it was providing clearer sight for users.
- There was extra gesture option to ease the use of large multi touch display for Zoom In gesture and Zoom Out gesture. It provided user to zoom in and zoom out quickly.
- It was easy to give command for moving objects with the help of the screen size.
- Users were working on the device by sitting, so it was hard to use upper side of the screen.

- The device requires calibration very often because of its size.
- There is a need for a window to follow moving objects on the application like soldiers and vehicles.
- Some users were not familiar with some standard gestures like Rotate gesture, so they had difficulties to understand the usage of such gesture.
- The device uses infrared (IR) frame to sense touch gestures. Because of the size of the screen, sometimes the other fingers can be sensed as touch gestures by the device. There can be made enhancement about gesture sensitivity of the device.

CHAPTER V

DISCUSSION AND CONCLUSION

This chapter includes discussion of the results obtained from two different methods, namely end user usability testing and interviews, and conclusion of the study pointing out design suggestions for large multi touch displays. Moreover, this chapter presents contribution of the study, guidelines for designers and developers, limitations of the study and future research.

5.1 DISCUSSION

Devices with touch sense technology have become an indispensable part of people' lives. The increasing use of these devices has brought significant changes on Human Computer Interaction (HCI). According to this change, the demand of users about the screen size of these devices is increasing day by day. They started to desire for using larger screens with touch sense ability for their daily activities or for their jobs. Using devices by touching has become a common thing for users. Touch technology entered the people' lives in many areas such as education, military, medical and entertainment. According to Martin-Dorta, Saorin, and Contero (2011), the touch screen interfaces increase the motivation and satisfaction of the students during the interactive courses.

The current design of operating systems or applications for touch devices are more suitable for small screen devices like smart phones, tablet PCs, laptops and desktop PCs whose display sizes are between 3 inches to 27 inches. However, the operating systems or design suggestions for such systems are not applicable for large multi touch displays. There are two types of the large screens according to the setup position of the displays, namely, walltop displays and tabletop displays. The walltop displays are placed perpendicular to the ground and the tabletop displays are the ones which are parallel to the ground. For this study, a walltop display whose display size is 143 inches (5 X 55 inches) was used in order to investigate the usability factors of large multi touch displays and make suggestions for the design of these displays.

The results of this study have been used to answer the following research questions:

RQ1 - What do the usability factors influence participants on using very large multi touch displays?

This study investigated the usability factors of large multi touch displays by comparing the user experiences of expert user and non-expert users via the data gathered from eye tracking device and by analyzing the interview results of these users. For this study, a task on large multi touch display was created. This task includes all possible gestures which were supported by these display. According to the eye tracking data related to Area of Interest (AOI) of Test

1 and Test 2, both expert user and non-expert users focused on the out of menu area more than menu area in durations for total task.

The results of this study showed that users who used the large multi touch display system transferred their previous habits and it was easy for users to adapt gestures provided by the system. The previous habits of the users were based on their usage of mobile devices like mobile phones. Bellucci, Malizia and Aedo (2014) figured out that touch gestures for large touch surfaces can be generated from the gestures for small devices like mobile devices, because it provides user acceptance about such gestures.

According to the results of this study, it was easy to select objects, manage the area, see the objects on the screen, and interact with two hands. These results comply with the results of a study in literature which pointed out that the most cited reasons of users for liking the public large multi touch system, which was provided for the study, were its simplicity/ease of use (12.9%), interactivity (12.4%) and multi touch (10.1%) (Jacucci, Morrison, & Richard, 2010). In addition, Liu and Chapuis (2014) pointed out that wall size display system is significantly effective for managing the difficult tasks.

According to the results of this study, users were satisfied about using the large multi touch display system. This result complies with the result of a study which found out that user satisfaction was improved notably and they felt more comfortable about using drag and drop operations on large multi touch system rather than using traditional drag and drop operations on a desktop PC via mouse operations (Doeweling, 2010). Besides, another study stated that all of the participants of the study were satisfied with their work on large multi touch display system, because they felt they worked effectively (Jakobsen & HornbÆk, 2014).

The results of this study indicated that it was hard to use upper side of the screen because of the position of the users while using the system. Users were sitting in front of the system and using the system by touching. Therefore, it was difficult to reach upper side of the screen. The design of the display can be changed in accordance of users' needs because there are unused spaces on the display.

According to interview results of this study, the type of touch sense of the system can be improved in terms of hardware or software. The type of touch sense of the system is based on infrared frame. While trying to touch on the screen, the other fingers of the users can enter the sense area of the infrared frame. Then, the system can perceive this unwanted action as touch operation.

RQ2 - What design suggestions can be given for very large multi touch display based systems?

According to the data from tracked area of the users and the data from the AOIs of users, eye movements of both expert user and non-expert users were around the center of the screen. It means that the focus of the users was in line with the eye level of users. This result complies with the result of a study in the literature which stated that 81% of the mouse events of the users were around the center of the screen, when they worked on large display (Bi & Balakrishnan, 2009). These results show that notifications or pop-up windows of the applications which are designed for large multi touch display based systems should be around the center of the screen. Designers should consider that AOIs of users are mostly around the center of the screen while using large multi touch displays.

The gesture counts for Test 1 and Test 2 show that the most common used gesture is tap gesture for all users. The study of Epps et al. (2006) has also same results about the common used gesture on large multi touch displays. It stated that the frequency of usage of tap gesture was 70.1% for all tasks. In addition, the results of this study pointed out that usage counts of tap gesture and drag gesture which are single input gestures are higher than the other gestures. This result is in agreement with the study which states that the usage of single touch input on a large multi touch screen occurred more than multi touch input (Chaboissier, Isenberg, & Vernier, 2011). These results show that designers should take into account that the most common gestures for large multi touch display based systems are one handed single touch gestures. They should provide important and common used actions with one handed single touch gestures.

During the analysis of the eye tracking data of users, it was observed that users preferred to use both of their hands for multi touch gestures like Zoom In gesture, Zoom Out gesture and Rotate gesture. It means that users used both of their hands to perform multi touch gestures instead of single hand. This is because the size of the display was larger and it took time to perform gestures like Zoom In, Zoom Out and Rotate by using single hand. These results show that developers should consider two handed usage of gestures, while defining multi touch gestures for applications developed for large multi touch display based systems.

According to Test 1 and Test 2 results, expert user mostly used menu to select objects on the screen, while non-expert users preferred to use area to make selections. It means that expert user knows the capability of the menu items and preferred to select objects on the screen by using the menu items. Therefore, non-expert users lost more time and completed the task after expert user. These results suggest that designers should consider tendency of non-expert users about not using shortcuts like menu items. Accordingly, designers should make the menu items easy to realize and use in order to save the time spent to complete the task.

As a result, the following table (Table 79) indicates the findings of the study and confirmed findings from the literature.

Table 79 - Findings of the Study

Findings of the Study	**Confirmed Findings from Literature**
Both expert user and non-expert users focused on the out of menu area more than menu area in durations for total task.	Finding from this study
Users who used the large multi touch display system transferred their previous habits and it was easy for users to adapt gestures provided by the system.	Bellucci, Malizia and Aedo (2014)
It was easy to select objects, manage the area, see the objects on the screen, and interact with two hands.	Jacucci, Morrison, & Richard (2010), Liu and Chapuis (2014)
Users were satisfied about using the large multi touch display system.	Doeweling (2010), Jakobsen & HornbÆk (2014)
It was hard to use upper side of the screen because of the position of the users while using the system.	Finding from this study.
The type of touch sense of the system can be improved in terms of hardware or software.	Finding from this study.
Eye movements of both expert user and non-expert users were around the center of the screen.	Bi & Balakrishnan (2009)
The most common used gesture is tap gesture for all users.	Epps et al. (2006)
Usage counts of tap gesture and drag gesture which are single input gestures are higher than the other gestures.	Chaboissier, Isenberg, & Vernier (2011)
Users preferred to use both of their hands for multi touch gestures like Zoom In gesture, Zoom Out gesture and Rotate gesture.	Finding from this study.
Expert user mostly used menu to select objects on the screen, while non-expert users preferred to use area to make selections.	Finding from this study.

5.2 CONCLUSION

In this study, a large multi touch display system was examined in terms of usability factors and design suggestions for the system. Firstly, the literature was scanned in order to understand the existing researches about touch technology, touch interfaces, touch gestures, very large displays and large multi touch display systems. Then, a task was determined for implementing the end user usability tests with expert user and non-expert users. During the end user usability tests, eye movement data of participants were recorded via glasses type eye tracking device. In addition, the test environment was recorded with two video cameras. After that, interviews were conducted with participants about their experiences with large multi touch display system. After collecting the data, it was analyzed and interpreted in order to explain the usability factors and design suggestions for the system.

The results of this study showed that the focus of users was generally at the center of the large multi touch display system. According to the transition counts of users on inside of menu, outside of menu and objects, both expert user and non-expert users were cognitively active during their experiences with the software. It means that eye movements of users were moving around the screen actively instead of focusing on a specific area on the screen. In addition, single touch gestures were the most common used gestures during their experiences with the system. Besides, the adaptation of users to the system, the management of the working area, and the interaction with two hands were easy. As a result, all of these increased the satisfaction of users about their experiences with the system.

5.3 CONTRIBUTION OF THE STUDY

In the past, people were interacting with the devices like computers or mobile phones by pressing keys or buttons. The interaction with these kind of devices was provided with apparatus such as keyboard or mouse. With the help of technological developments, touch sense devices entered people' lives. At the beginning of the usage of touch sense devices, people were started to use apparatus like stylus pen to interact. Then, using devices like smart phones and tablet PCs by touching with fingers started to be popular. People started to use their devices by touching without the help of any kind of apparatus in their daily lives. After that, the size of touch sense devices started to increase day by day. Therefore, there is an increasing demand for adaptation of the human computer interfaces of devices which have small screen sizes to the interfaces of devices which have larger screen sizes. In order to evaluate the usability of devices and their interfaces, it is important to provide user satisfaction and make the usage of the devices more effective. The most common method is the end user usability testing. There are studies in literature about usability factors of small screen devices, but the studies on larger screens are insufficient. The screen sizes of the devices are increasing rapidly. Therefore, the usability factors and design of large multi touch displays should be investigated.

This study contributes to the Human Computer Interaction literature by stating the usability factors of large multi touch displays and the suggestions for the design of these displays. The findings of the study showed that it is easy to adapt to use large multi touch displays for users. Also, the management of the data in these displays is easy because it enables users to see more data simultaneously than smaller displays. In addition, expert users make more interaction than non-expert users in terms of usage of touch gestures. Moreover, the design of the display can be changed in accordance of users' needs because there are unused spaces on the display in this study. These results can be a guide for manufacturers and developers of the systems and for applications which are appropriate for these kind of devices.

5.4 GUIDELINES FOR DESIGNERS AND DEVELOPERS

While designing a software for large multi touch displays, there are some guidelines to be considered to reach better results in terms of usability of software. These guidelines are related with both design of large screen and design for intended software. These guidelines can be listed as follows:

- If gestures from previous experiences of users with smart devices such as smart phones and tablet PCs are used, it might help to adapt gestures which are used in large multi touch displays.
- Large multi touch displays should provide environment close to real life in term of size of the objects in order to make users satisfied.
- Notifications appearing on the screen should be on the eye level of users. If they appear above the eye level of users or below the eye level of users, users might have problems to aware of them.
- Menus which are planned to use on the screen should be designed flexible. User should control over menus. In other words, users should have the chance to move or replace the menu on the screen according to their usage positions such as sitting in front of the screen or standing in front of the screen.
- Applications for large multi touch displays should be designed by considering the position of users such as sitting in front of the screen or standing in front of the screen. To illustrate, the upper side of the screen can be useless, if users use the screen by sitting in front of it.
- While designing a software for large multi touch displays, gestures should be created or determined by considering sensitivity of touch screen in order to prevent unintended gesture recognition like entrance of unintended fingers inside the touch recognition area.
- While designing a software for large multi touch displays, there should be options to follow active objects. This is because the size of the display is larger and it can be hard for users to control the objects in the application.
- While designing a software for large multi touch displays, a simulation can be provided for making practice to overcome familiarity problems with gestures which users are not familiar with.

5.5 LIMITATIONS AND FUTURE RESEARCH

There are several limitations of this study. The first limitation is that the participants of the study were not the actual users of the system, instead they were working on the project from which the data of this study were collected. Expert User 1 is the test engineer in the project and Non-Expert User 1 (NEU 1), Non-Expert User 2 (NEU 2) and Non-Expert User 3 (NEU 3) are the software engineers in the project. Therefore, it is recommended that future studies should be done with actual users of the system.

The second limitation of the study is that the pilot study for interviews was not applied, because there was limited number of users who can use the application which was used to gather data for this study. Therefore, users who worked in the development process of the application were selected as participants of this study. Thus, it is recommended that future studies should include more users and pilot study for interviews should be applied.

The final limitation of the study is that the head movements of the participants during pilot test and actual tests of this study were ignored during the analysis of the eye movement data of participants. Therefore, it is recommended that the head movement data should be gathered

in the further studies and considered during the analysis of the eye movement data of participants.

Further studies can be conducted to figure out the usability factors and design suggestions for large multi touch displays by making comparison between walltop displays and tabletop displays.

REFERENCES

Andrews, C., Endert, A., & North, C. (2010). Space to think: large high-resolution displays for sensemaking. *… of the SIGCHI Conference on Human …*, 55–64. Retrieved from http://dl.acm.org/citation.cfm?id=1753336

Bellucci, A., Malizia, A., & Aedo, I. (2014). Light on horizontal interactive surfaces: Input space for tabletop computing. *ACM Computing Surveys (CSUR)*, *46*(3). Retrieved from http://dl.acm.org/citation.cfm?id=2500467

Bi, X., Bae, S., & Balakrishnan, R. (2014). WallTop: Managing Overflowing Windows on a Large Display. *Human–Computer Interaction*, 1–59. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/07370024.2013.812411

Bi, X., & Balakrishnan, R. (2009). Comparing usage of a large high-resolution display to single or dual desktop displays for daily work. *The SIGCHI Conference*, 1005. doi:10.1145/1518701.1518855

Bordin, S., Zancanaro, M., & Angeli, A. De. (2013). Touching dante: a proximity-based paradigm for tabletop browsing. *… of the Biannual Conference of the …*. Retrieved from http://dl.acm.org/citation.cfm?id=2499172

Buxton, B. (2009). http://www.billbuxton.com/multitouchOverview.html, 1–10.

Buxton, W., Hill, R., & Rowley, P. (1985). Issues and Techniques in Touch-Sensitive Tablet Input, *19*(3), 215–224.

Chaboissier, J., Isenberg, T., & Vernier, F. (2011). RealTimeChess: lessons from a participatory design process for a collaborative multi-touch, multi-user game. *Conference ITS'11*, *November*, 97–106. doi:10.1145/2076354.2076374

Czerwinski, M., Smith, G., Regan, T., Meyers, B., Robertson, G., & Starkweather, G. (2003). Toward characterizing the productivity benefits of very large displays. In *Proc. Interact* (Vol. 3, pp. 9–16).

Czerwinski, M., Tan, D. S., & Robertson, G. G. (2002). Women Take a Wider View. In *Proceedings of {ACM} {CHI} 2002* (Vol. 4, pp. 195–202). doi:10.1145/503376.503412

Dietz, P., & Eidelson, B. (2009). SurfaceWare: dynamic tagging for Microsoft Surface. *… of the 3rd International Conference on Tangible …*, 249–254. Retrieved from http://dl.acm.org/citation.cfm?id=1517717

Dimond, T. L. (1957). Devices for reading handwritten characters. *IRE-ACM-AIEE '57 (Eastern): Proceedings of the Eastern Joint Computer Conference: Computers with Deadlines to Meet*, 232–237. doi:10.1145/1457720.1457765

Doeweling, S. (2010). Drop-and-drag: easier drag & drop on large touchscreen displays. *Proceedings of the 6th Nordic Conference*, 158–167. doi:10.1145/1868914.1868936

Epps, J., Lichman, S., & Wu, M. (2006). A study of hand shape use in tabletop gesture interaction. *CHI '06 Extended Abstracts on Human Factors in Computing Systems - CHI EA '06*, 748. doi:10.1145/1125451.1125601

Gestures | Android Developers. (n.d.). Retrieved May 14, 2015, from http://developer.android.com/design/patterns/gestures.html

Goldberg, H. E. (1915). *Controller*. *United States Patent 1,117,184*. Retrieved May 28, 2015, from http://www.freepatentsonline.com/1117184.pdf

Grissom, S. (2008). iPhone application development across the curriculum. *Journal of Computing Sciences in Colleges*, *24*(1), 40–46.

Hao, X., & Kui, H. (2014). A Low-Power Ultra-Light Small and Medium Size Acoustic Wave Touch Screen. *Applied Mechanics and Materials*, *513-517*, 4072–4075. doi:10.4028/www.scientific.net/AMM.513-517.4072

Hey, T., & Pápay, G. (2014). *The Computing Universe: A Journey through a Revolution*. Cambridge University Press. Retrieved from https://books.google.com/books?id=NrMkBQAAQBAJ&pgis=1

Jacucci, G., Morrison, A., & Richard, G. (2010). Worlds of information: designing for engagement at a public multi-touch display. *Proceedings of the …*, 2267–2276. Retrieved from http://dl.acm.org/citation.cfm?id=1753669

Jain, A., Bhargava, D., & Rajput, A. (2013). TOUCH-SCREEN TECHNOLOGY. *International Journal of Advanced Research in Computer Science and Electronics Engineering*, *2*(January), 74–78. Retrieved from http://www.ijarcsee.org/index.php/IJARCSEE/article/view/309

Jakobsen, M. R., & HornbÆk, K. (2014). Up close and personal: Collaborative work on a high-resolution multitouch wall display. *ACM Transactions on Computer-Human Interaction*, *21*(2), 1–34. doi:10.1145/2576099

Kolokowsky, S., & Davis, T. (2009). Touchscreens 101 : Understanding Touchscreen Technology and Design, (June 2009), 1–5. Retrieved from http://www.cypress.com/?docID=17212

Liu, C., & Chapuis, O. (2014). Effects of display size and navigation type on a classification task. *Proceedings of the …*, 4147–4156. doi:10.1145/2556288.2557020

Malik, S., Ranjan, A., & Balakrishnan, R. (2005). Interacting with large displays from a distance with vision-tracked multi-finger gestural input. *Proceedings of the 18th*

Annual ACM Symposium on User Interface Software and Technology - UIST '05, 43. doi:10.1145/1095034.1095042

Martin-Dorta, N., Saorin, J., & Contero, M. (2011). Web-based Spatial Training Using Handheld Touch Screen Devices. *Educational Technology & Society*, *14*, 163–177. Retrieved from http://www.ifets.info/others/download_pdf.php?j_id=52&a_id=1160

Micire, M., Desai, M., Courtemanche, A., Tsui, K. M., & Yanco, H. a. (2009). Analysis of natural gestures for controlling robot teams on multi-touch tabletop surfaces. *Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces - ITS '09*, 41. doi:10.1145/1731903.1731912

Ni, T., Schmidt, G. S., Staadt, O. G., Livingston, M. A., Ball, R., & May, R. (2006). A survey of large high-resolution display technologies, techniques, and applications. In *Proceedings - IEEE Virtual Reality* (Vol. 2006, p. 31). doi:10.1109/VR.2006.20

Norman, D. (1988). The Psychology of Everyday Things. In *The Psychology of Everyday Things* (pp. 1–104). doi:10.2307/1423268

Pages for iOS (iPad): Touchscreen basics. (n.d.). Retrieved May 14, 2015, from https://support.apple.com/kb/PH3571?locale=en_US&viewlocale=en_US

Schade, A. (2015). *Large Touchscreens: What's Different?* Retrieved May 28, 2015, from http://www.nngroup.com/articles/large-touchscreens/?utm_source=Alertbox&utm_campaign=a321a781b5-Large_Touchscreens_05_04_2015&utm_medium=email&utm_term=0_7f29a2b335-a321a781b5-24300665

Thompson, M., Nordin, A., & Cairns, P. (2012). Effect of touch-screen size on game immersion. *Proceedings of the 26th Annual BCS …*. Retrieved from http://dl.acm.org/citation.cfm?id=2377952

Touch: Swipe, tap, and beyond. (n.d.). Retrieved May 14, 2015, from http://windows.microsoft.com/en-us/windows-8/touch-swipe-tap-beyond

Wahab, N., & Zaman, H. B. (2013). The Significance of Multi-Touch Table in Collaborative Setting: How Relevant this Technology in Military Decision Making. *Applied Mechanics and Materials*, *278-280*, 1830–1833. doi:10.4028/www.scientific.net/AMM.278-280.1830

Wei, Z., Liu, W., He, Q., & Wei, N. (2011). The design of infrared touch screen based on MCU. *… (ICIA), 2011 IEEE …*, (June), 485–489. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5949041

APPENDICES

APPENDIX A: INTERVIEW QUESTIONS (TURKISH)

1) Cinsiyetiniz?

2) Yaşınız?

3) Eğitim durumunuz nedir?

4) Mesleğiniz nedir? Deneyim süreniz?

Sıradaki sorular görevin kendisi değil de, görevi yerine getirirken izlenen süreç dikkate alınıp cevaplandırılmalıdır. Örneğin, ekranı büyütüp küçültme, ekranda bir şey seçme, bir veri girişi yapma vb.

5) Uygulamada zorlandığınız kısımlar oldu mu? Hangi kısımda zorlandınız? Nasıl çözülebilir?

6) Ekran boyutunun avantajları ve dezavantajları nelerdir?

7) Alışık olduğunuzdan farklı dokunmatik hareketler (Gesture) var mıydı? Varsa ne gibi etkileri oldu? Kullanmakta zorlandınız mı? Gesture önerileriniz var mıdır?

8) Kullanımı etkileyen faktörler konusunda önerileriniz var mı? Varsa bunlar nelerdir?

APPENDIX B: VOLUNTARY PARTICIPATION FORM (TURKISH)

Sayın Katılımcı;

Bu çalışma Orta Doğu Teknik Üniversitesi Enformatik Enstitüsü Bilişim Sistemleri Bölümü'nde yürütülmekte olan "Büyük Boyutlu Çoklu Dokunmatik Arayüzler: Kullanılabilirlik ve Tasarım Boyutlarının Araştırılması" başlıklı yüksek lisans tez çalışmasının bir parçasıdır.

Bu çalışmada "Büyük Boyutlu Çoklu Dokunmatik Arayüz" kullanmanız istenecektir. Uygulama süresince "Gözlük Şeklinde Göz Hareketleri Takip Cihazı" takmanız istenecektir. Bu cihaz aracılığı ile uygulama esnasında baktığınız yerler tespit edilecek ve bu veriler çalışmada kullanılacaktır. Ayrıca, uygulama esnasında sesli düşünmeniz istenecek ve video kaydı alınacaktır. Uygulama sonunda "Büyük Boyutlu Çoklu Dokunmatik Arayüz" kullanımınız hakkında sizinle bir görüşme yapılacak olup, bu görüşmenin ses kaydı alınacaktır. Çalışma süresince vermiş olduğunuz tüm bilgiler gizli tutularak, sadece akademik amaçlı kullanılacaktır.

Çalışmamız yaklaşık 90 dakika sürecektir ve katkılarınız için çok teşekkür ederiz.

TARİH

AD SOYAD

İMZA

APPENDIX C: ETHICS APPROVAL FORM (TURKISH)

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

DUMLUPINAR BULVARI 06800
ÇANKAYA ANKARA/TURKEY
T: +90 312 210 22 91
F: +90 312 210 79 59
ueam@metu.edu.tr
www.ueam.metu.edu.tr

Sayı: 28620816/574-1118

29.11.2014

Gönderilen : Prof. Dr. Kürşat Çağıltay
Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü

Gönderen : Prof. Dr. Canan Sümer
IAK Başkanı Vekili

İlgi : Etik Onayı

Danışmanlığını yapmış olduğunuz Bilişim Sistemleri Bölümü öğrencisi Mehmet Dönmez'in "Büyük Boyutlu Çoklu Dokunmatik Arayüzler: Kullanılabilirlik ve Tasarım Boyutlarının Araştırılması" isimli araştırması "İnsan Araştırmaları Komitesi" tarafından uygun görülerek gerekli onay verilmiştir.

Bilgilerinize saygılarımla sunarım.

Etik Komite Onayı

Uygundur

29/11/2014

Prof.Dr. Canan Sümer
Uygulamalı Etik Araştırma Merkezi
(UEAM) Başkanı Vekili
ODTÜ 06531 ANKARA

TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü ☐
Sosyal Bilimler Enstitüsü ☐
Uygulamalı Matematik Enstitüsü ☐
Enformatik Enstitüsü ☐
Deniz Bilimleri Enstitüsü ☐

YAZARIN

Soyadı : ……
Adı : ……
Bölümü : ……...

TEZİN ADI (İngilizce) : ……....
……
……
……
……...

TEZİN TÜRÜ : Yüksek Lisans ☐ Doktora ☐

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir. ☐
2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir. ☐
3. Tezimden bir (1) yıl süreyle fotokopi alınamaz. ☐

TEZİN KÜTÜPHANEYE TESLİM TARİHİ : …….