GUIDELINES AND PRINCIPLES FOR EFFICIENT INTERACTION ON LARGE TOUCHSCREENS WITH COLLABORATIVE USAGE

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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 work.

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ABSTRACT

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Understanding collaborative usage of large-size screen systems is important for advancing the general study of human-computer interaction (HCI) as well as for guiding the designers while creating efficient interactive large-size systems. This thesis aims to provide guidance for the designers of collaborative large-size screen systems. It therefore gives background information about such systems, defines similarities and differences in existing systems, compares existing design guidelines and principles, tests and validates proposed solutions and offers new guidelines and principles for designing interactive large-size screen systems. In the first part, a literature survey of input devices, output devices, interaction methodologies and collaborative interaction used for large-size screen systems was conducted. This showed that an empirical, systematic and academic study for guiding the design process of collaborative large-size systems is missing. Following a literature review of research methods in the HCI field, an initial system was setup, a gesture library was created and user interface (UI) elements were generated to gather initial findings. Existing design guidelines and principles of well-known platforms were compared and compatible ones were used as input for creating new ones. Thereafter, an empirical laboratory experiment with four major tests, was conducted to test interaction devices, multi-user interaction, collaborative usage and UI elements on a large-size touchscreen system. The results and conclusions of this research should help to inform the design and development of similar HCI systems.

Keywords: large screen systems, large screen collaborative usage, human computer interaction, user interfaces, collaborative interaction

ÖZ

İŞBİRLİKÇİ KULLANIM İLE BÜYÜK DOKUNMATİK EKRANLARDA VERİMLİ ETKİLEŞİM İÇİN KILAVUZ VE KURALLAR

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Büyük ekranlı sistemlerin işbirlikçi kullanımını anlamak genel insan-bilgisayar etkileşimi geliştirmek ve tasarımcıları yeni etkili etkileşimli sistemler geliştirirken yönlendirmek için önemlidir. Bu tez, işbirlikçi büyük ekranlı sistemlerin tasarımcılarına yardımcı olmayı amaçlamaktadır. Bu sebeple, bu tür sistemler için artalan bilgisi sağlar, bu sistemlerle var olan sistemlerin benzerliklerini ve farklılıklarını tanımlar, mevcut kılavuz ve kuralları karşılaştırır, önerilen çözümleri test eder ve yeni kılavuz ve kurallar üreterek yönlendirme sağlar. İlk kısımda, büyük ekranlı sistemlerin girdi aygıtlarının, çıktı aygıtlarının, etkileşim yöntemlerinin ve işbirlikçi kullanımın literatür taraması yapılmıştır. Bu göstermiştir ki, işbirlikçi büyük ekranlı sistemlerin tasarım sürecini yönlendirecek, deneysel, sistematik ve akademik bir çalışma yoktur. İnsan-bilgisayar etkileşimi alanında araştırma yöntemleri için yapılan literatür araştırması sonucunda, ilk verileri toplamak için prototip bir sistem kurulmuş, temel bir hareket kütüphanesi oluşturulmuş ve kullanıcı arayüzü elemanları geliştirilmiştir. Tanınmış platformların mevcut tasarım kılavuz ve kuralları karşılaştırılmış ve uygun olanlar yenilerini oluşturmak için kaynak olarak kullanılmıştır. Daha sonrasında, dört ana testten oluşan deneysel bir laboratuvar deneyi ile büyük ekranlı sistemlerde girdi yöntemleri, çok kullanıcılı etkileşim, işbirlikçi kullanım ve arayüz elemanları test edilmiştir. Bu tezin bulgu ve sonuçları, benzer etkileşim sistemlerinin tasarım ve geliştirme süreçlerine kaynak oluşturarak yardım edebilir.

Anahtar Sözcükler: büyük ekranlı sistemler, büyük ekran işbirlikçi kullanım, insan bilgisayar etkileşimi, kullanıcı arayüzleri, işbirlikçi etkileşim

Dedicated to my family, whose support I have always felt…

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LIST OF ABBREVIATIONS

GTEC	Group Touch Error Count
GTHT	Group Touch Hit Time
GTSCDiff	Group Touch Shown – Clicked Difference
HCI	Human-Computer Interaction
IMHT	Individual Mouse Hit Time
IMSCDiff	Individual Mouse Shown – Clicked Difference
ITHT	Individual Touch Hit Time
ITSCDiff	Individual Touch Shown – Clicked Difference
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MEC	Mouse Error Count
MHT	Mouse Hit Time
MM	Menu Move
MR	Menu Rotate
MSCDiff	Mouse Shown – Clicked Difference
MZ	Menu Zoom
OLED	Organic LED
PPI	Pixel per Inch
TAM	Technology Acceptance Model
TEC	Touch Error Count
THT	Touch Hit Time
TSCDiff	Touch Shown – Clicked Difference
UE	User Experience
UI	User Interface
UWP	Universal Windows Platform
UX	User Experience

CHAPTER 1

INTRODUCTION

In the first chapter, the background, purpose and significance of the study are given. The proposed methodology is also provided at the end of this chapter.

1.1. Background of the Study

HCI is a discipline that is primarily concerned with the design and implementation of human-centric interactive information systems. The concept covers several issues of people interacting with computer systems. The HCI performance of a system depends on its usability, which is associated with the elegance and clarity of the interaction with a computer program. Usability is also directly related to the hardware employed. Several studies have sought to improve the usability of the existing systems and some commercial solutions have also been proposed. Desktop-size screen systems have been in existence since the first years of 20th century and much of the development of HCI has been focused on them. Similarly, considerable investment was made in affording interaction solutions for mobile-size systems. However, large-size screen systems are fairly new in the field and several issues remain regarding their interaction.

The introduction of large-size screen interaction goes back to the early 1990s. Large-size screens can be described as screens that allow multiple collaborating users to stand in front of them and to interact in comfort. The nature of such systems means that several users can use the screen simultaneously but a lack of dynamic content indicates that the possibilities of collaborative usage, with two or more people using the same UI together, have not been fully realized. Further HCI research is necessary to produce better, more user friendly solutions for large-size screen systems and to consider ways to enhance their collaborative usage.

1.2. Purpose of the Study

Today, our daily life depends on information systems more than ever. Therefore, concepts such as usability of information systems are a trending topic. Usability and interaction of systems has different features and aspects when the physical properties of systems are considered. Accordingly, desktop-size and mobile-size screen systems share similarities and differences with large-size screen systems. However, these have not yet been identified systematically and large-size screen systems remain to be tested in a controlled environment for academic purposes. A laboratory experiment to test several aspects of large-size screen systems and collaborative usage on large-size screen systems is still missing. There are no significant HCI guidelines and principles for designers to reference when they are designing the human-computer interaction of large-size screen systems for collaborative usage.

Based on the purposes mentioned above, the following problems are considered throughout the study:

1) A complete applied research for creating the initial setup, controlled laboratory experiments for making proper observations and systematic statistical analysis for obtaining correct analytical results of large-size screen systems are missing in the field.

2) Differences and similarities of large-size screen systems versus desktop-size and mobile-size screen systems are not properly defined.

3) Comparison of interaction design guidelines for well-known platforms has not been made.

4) An empirical evaluation of usability and collaborative interaction for large-size screen systems has not been made.

5) A guidelines and principles collection for designing large-size screen systems' human-computer interaction is required.

5.1. Significance of the Study

Interaction design is now widespread in product development. In particular, website consultants, global corporations, computing industries and all similar other work environments have all realized its pivotal role in successful interactive products. Interaction design process is considered to be good if the design process is user-centric. User experience (UX) is also a trending topic and currently it is at the core of usability engineering and interaction design. Usability and interaction are developed according to better UX requirements.

In the world of information systems, personal computers are converting to social computers and designers have had to change their approach according to this trend in user demands. Ubiquity of systems was the first solution developed for the problem; however, it is still very difficult or sometimes impossible for several collaborating users to work or study on the same shared content from a distance or from different machines. With the new requirements and demands in mind, a general design guidelines and principles collection is required for designers as a reference. To provide such a source, a series of academic research and experiments are necessary.

Designing efficient interaction methodologies for collaborative usage of large-size systems, therefore, requires a systematic approach to formalize the problem and solve it scientifically. To the best of our knowledge, this is the first study of large-size screen systems that gathers usage statistics, compares existing interaction design guidelines and principles, tests usability systematically in a laboratory environment, analyzes the data statistically and provides new guidelines and principles necessary when designing for large-size touchscreen systems and bidding to realize their potential for collaborative usage.

5.2. Methodology of the Study

Our approach to define usability and interaction design guidelines and principles is as follows: We, firstly, have searched the literature to find out which research methods are used most for human-computer interaction. According to the results, we have identified which methods to use in specific research areas. Then we searched the literature for related studies. After that, we set up a prototype system to run a military simulation considered as a serious game to observe the users for usage details. We have created a gesture library and menu based UI library for the users to use on large-size screen systems. We have observed the collaborating users and asked them their ideas about UX. As the result of these observations and examinations, usability differences and similarities among large-size screen systems, desktop-size systems and mobile-size systems are defined. Then we have searched the literature for guidelines and principles related to desktop-size and mobile-size screen systems. We have used these guidelines and principles to enhance our differences and similarities list and to create our initial guidelines and principles for large-size screen systems. We then set up a laboratory test environment and ran four major tests to evaluate our guidelines and principles and write new ones. Finally, we statistically analyzed and discussed our test results.

This document is organized as follows: Chapter 2 covers the related work about input technologies, display technologies, large-size screen interaction and usability of systems. Chapter 3 describes setup, gesture and UI library, and research methods for HCI. Chapter 4 defines differences and similarities of large-size screen systems with respect to desktop-size and mobile-size screen systems. Chapter 5 discusses guidelines and principles of desktop-size and mobile-size screen systems. Chapter 6 explains the laboratory experiments, results and evaluation. Chapter 7 provides the proposed guidelines and principles. A discussion is given in Chapter 8. Chapter 9 concludes the study.

CHAPTER 2

RELATED WORK

This chapter provides background information about existing input devices, display technologies, input techniques, usability issues, large-size screen systems, collaborative interaction and human computer interaction design methodologies. In the first section, an overview of input devices is given. In the second section, an overview of display technologies is given. The third section looks into input technologies, usability issues, large-size screen interaction and collaborative interaction.

2.1. Human-Computer Interaction

J. C. R. Licklider defines man-computer interaction in his study (Licklider, 1960). He says that human and computer will be closely integrated in the following years with the help of new technologies and the main aim of building useful interaction systems is to enable people to use systems more efficiently. He expresses that interaction systems should assist people while using computers and help them to make decisions while interacting with them.

The technology that enables users to interact with computers consists of two main parts, which are, input devices used for interaction and output devices used to see the effect of the interaction. Output devices which do not receive input have matured to a level for which further improvements are thought negligible. Thus, currently the main focus is on interactive displays. A variety of touchscreen technologies, such as multi-touch displays, have emerged in the market and have been adapted for use on large displays. These new modes of immersive interaction necessitate collaborative input modalities for multi-user large-size screens.

A number of studies that have been undertaken on large-size screen collaborative interaction. These studies are explained in detail below.

2.2. Input Technologies

In this section, detailed information about several different input technologies is provided. Data entry, pointing, data manipulation and several different input styles are discussed.

2.2.1. Textual Input

The primary textual input device for computers is still the keyboard. Most people use a keyboard almost every day and user levels differ dramatically. Beginners can enter text at a speed of 1 keystroke per second, average office users have a speed of 5 keystrokes per second and expert users have a speed of up to 15 keystroke per second. Generally, keyboards enable their users to press only a single key at a time. However dual keypresses also are available for Shift, Alt and similar keys to enable users to use alternatively the keys. Some expert users specifically assign shortcuts to their keyboard for faster interaction with applications. Expert users are also noted to prefer to use their keyboard for navigation and application switching purposes instead of pointing devices. Keyboards are really fast input devices as they enable their users to enter data with several finger simultaneously or in a very short time interval. Some 10 finger users are so fast that they can provide dense textual data that no mobile device users can reach with virtual on-screen keyboards.

Different keyboard sizes and layouts are being built for different needs. It is known that experienced users prefer specially designed keyboards and use them more efficiently. However large keyboards and more specialized keyboards can be difficult for novice users. Single handed keyboards also exist to enable users to both using keyboards and to manipulate other objects.

On-screen keyboards are also widely used as they do not require any extra hardware. They are a popular feature of mobile devices as users do not need to carry any extra hardware and they can assign the required space to display elements. These keyboards can be expanded and collapsed and this enables more efficient use of the small screen. When keyboard activity is required, the keyboard appears on the screen and users can provide simple data entry easily. One other advantage is that the layout of the keyboard can easily be changed. Users can select from QWERTY, ABCDE or emoji keyboard layouts that are widely used on social apps.

During the development of the mobile devices, a variety of physical and virtual keyboards were offered. At first, only numeric keyboards were available, then small QWERTY keyboards were attached to some mobile devices. These small keyboards, while initially popular, were largely replaced with the introduction of auto-complete techniques such as T9. This enabled faster data entry by employing dictionary based databases to predict the word a user is trying to enter and then automatically presenting a suggestion to them. Auto completion went on to be rapidly adopted by most users.

With the arrival of smartphones, interaction changed dramatically. Apple began to use a full-size touchscreen for all interaction on pointing, drawing, gesturing and texting. On-screen keyboards became the dominant texting interaction method for mobile devices (Dunlop & Masters, 2008; MacKenzie & Soukoreff, 2002). Over time a variety of other texting methods have started to emerge. Handwriting is one of these alternatives. Employing a stylus also enabled users to accurately and quickly provide data (Kristensson & Denby, 2009). Samsung has several models which use this principle. A similar approach to autocomplete is shorthand gesturing. This approach can be used instead of tapping on the keyboard.

Some specific languages such as Chinese and Japanese are good candidates for handwriting recognition. Other specific solutions for disabled people can increase the usability of dedicated devices. Similar solutions have also been developed for niche areas such as serious games and military applications. New design alternatives or best approaches have also been developed to better enable interaction with such applications.

Our target system would not require dedicated hardware for text input. A keyboard or similar device requires physical location on a dedicated table or tray. Large-size screen systems typically have vertical displays and people stand close to them, especially if pointing is performed with the help of touchscreen techniques. This makes it physically difficult to locate a separate keyboard or text input device for use with such systems. For this reason, on-screen keyboard solutions developed for mobile devices are widely used on large-size screen systems. When text needs to be entered the user simply selects a text field which prompts the appearance of the on-screen keyboard. To date, most large-size screen systems were built to present data to a user and not for entering textual data into a system. Need for textual input in collaboration is also small and in general only communication issues require some textual data. So, in terms of textual input on large-size screen systems most designers tend to apply the guidelines and principles developed for mobile devices. There are some exceptions, particularly in terms of the application of auto-complete techniques which are more suitable where dense data input and speed of entry is required. Collaborative users may also prefer not to use auto-completion on large-size screens as they may wish to enter novel or specific words and terminology that would not appear on standard vocabulary databases. In such situations, more specific guidelines and principles need to be generated for HCI on large-size screen systems.

2.2.2. Pointing Devices

Pointing devices and pointer based direct manipulation interaction is popular and widely used because users can avoid the need to learn commands and they can easily complete a desired action. Besides, errors are less common since choices are fewer and users' attention is maintained on the screen as they do not need to look at another device. Pointing devices have a high performance, low error rate, easy learning curve and high satisfaction compared to other interaction devices.

The tasks are divergent and the devices are fairly different to accomplish desired actions (Hinckley & Wigdor, 2002). This provides a wide gap for designers to design new interaction techniques. To fully understand the concept of pointing devices, it is better to first understand the pointing tasks and then develop appropriate devices.

2.2.2.1. Pointing Tasks

Pointing tasks are generally collected under 6 or 7 groups (Foley, Wallace, & Chan, 1984). These groups are as follows:

<u>Select:</u>

In this group, users choose an item from a set of items. It is generally used while choosing an option from a menu, marking an option or identifying an object.

Position:

In this group, users move the pointing cursor at a point in one, two, three or higher dimensional space. It is generally used while drawing, dragging or following an item on screen.

Orient:

In this group, users point the cursor to a direction in two, three or higher dimensional space. It is generally used while rotating, controlling something or pointing a direction.

Path:

In this group, users sequentially provide a series of position and orientation as the input. It is generally used while providing gestural input or manipulating something.

Quantity:

In this group, users provide numerical data to the system. It is generally used to enter some numeric parameter to a program.

Gesture:

In this group, users perform gestural data on the screen. It is generally used to provide fast commands which are usually the most used commands of the program.

Text:

In this group, users enter textual data onto a system in a two dimensional space. Besides simply providing letters, users are able to change the location and appearance of text, e.g. centering it, setting font size and highlighting.

It is possible to accomplish all of the above tasks with keyboards and similar devices, however most users prefer to use pointing devices as they are faster and less error prone. However, expert users tend to prefer to use dedicated keyboard shortcuts for frequent tasks such as copy and paste that enable users to achieve higher speeds of data entry and accuracy.

Pointing devices can be grouped into two different categories. These are direct-control and indirect-control devices. Direct-control devices enable the user to manipulate objects on the screen by touch or using a device such as a stylus. Indirect-control devices enable the user to manipulate objects away from the screen using a device such as a mouse, trackball, or joystick. Each group features a variety of devices and techniques that can be incorporated into designs to maximize performance and ease of use. The two groups are discussed below.

2.2.2.2. Direct-Control Pointing Devices

The first direct control devices were pen shaped pointing devices. Users could use the pen devices to touch anything on screen. These pen devices had buttons on them and users were able to give commands by pressing them. They were however difficult to carry these devices while using and each user had to have one to interact with the system. For this reason, touchscreen technology was rapidly adopted by designers and users.

Touchscreens allow their users to directly touch arbitrary locations on screens and to interact with the system. This technology has proved to be very robust and was rapidly applied to mobile devices and public kiosks. Touchscreens started to be the preferred choice on applications where users are novice and separate keyboards are not required. Designers like to use them for public-access systems because they contain no moving parts and their durability is very high. Touchscreens also enabled new solutions for people with physical disabilities who had interaction problems using keyboard devices. However, touchscreens have their own drawbacks such as arm fatigue.

The first touchscreen devices and drivers had several issues. They were not so accurate and had imprecise pointing problems associated with hardware limitations. Initial touch devices were based on physical pressure, impact or interruption of a grid of infrared beams. Later devices improved precision. Current technologies such as resistive, capacitive and surface-acoustic-wave have high resolutions and great precision. Land-on strategy (Potter, Weldon, & Shneiderman, 1988) which enables the users to directly select content was the first step to improve and increase the efficiency of touchscreens. An innovative design called lift-off strategy (Sears & Shneiderman, 1991) dramatically improved the usability of touchscreens. This strategy is described by Shneiderman (Shneiderman, 2010) as follows: “As users touch the screen, feedback is provided as to what will be selected and the action takes place when the finger is lifted off the screen. In our implementation a cursor was drawn on the screen slightly above the finger. When the cursor was over a target, the target was highlighted. Users could then either lift-off their finger to select the highlighted target, or adjust their position by sliding their finger to a neighboring target. This was a major breakthrough: only the cursor position mattered for the selection, not the finger itself. Selecting a single character was now possible.” Another improvement was the high-precision touchscreen strategy. It is again explained by Shneiderman (Shneiderman, 2010) as follows: “the next step was to try to stabilize the touchscreen so that the cursor would stay put when the finger didn't move. This was accomplished with a clever time-dependent averaging of the positions returned by the device. Now, individual pixels could be selected (in the 480x350 high resolution screen of the time). An experiment showed that there was significant difference in selection times and error rates between mouse and touchscreen for targets down to about 1mm2, when using a lift-off strategy with a stabilized touchscreen. Companies such as Elographics and Microtouch, with whom we had good relations, integrated stabilization techniques into the drivers of their touchscreens. From then on, high-precision was possible, and designers could do everything with the touchscreen that they could do with the mouse.” These two strategies enabled touchscreens to be used widely in many different domains and applications.

Using the natural touch of a finger now can simulate a click on screens of mobile and similar devices which can be held in the hand, attached to something or placed somewhere. Most touchscreens were initially used with a stylus which was unpopular with users and not widely adopted. However, in recent years, the stylus has proved more popular for use with smaller mobile devices as users can more accurately point to a desired location on a small screen than they can do with their finger. The stylus still needs to be both carried and manipulated to select and enter data on a small screen. Designers therefore favor solutions that enable users to do both simultaneously (Vogel & Baudisch, 2007). Further studies have been undertaken to distinguish the touch event of stylus and finger.

The development of touchscreen hardware has enabled developers to create a great variety of applications for touch based interaction. Designers of Apple's iPhone are leading the industry and almost every mobile device now uses touch based interaction and this approach is becoming the industry standard. New selection methods and soft keyboards are the taking place of pull-down menus and other UI elements. Designers are therefore striving to create new UI elements and designs for new market needs.

2.2.2.3. Indirect-Control Pointing Devices

Indirect-control pointing devices are widely used on desktop computers. The mouse is the best known example. They require cognitive capabilities and hand/eye coordination to move the on-screen cursor to a desired point. The mouse is one of the most used input devices because it is inexpensive and widely available. It is also comfortable to use since users can rest their arm on a desk while using it. It is easy to use a mouse because users use their forearm to move long distances and fingers to handle precise positioning. However, it has some disadvantages. First of all, it is an external hardware item and users need to hold it to use it. If it is cabled, it is difficult to manage the cord and battery powered devices are less reliable. Users also need to practice indirect controlling precisely. A desk area is required for the system to work. A variety of designs are employed and users are not agreed on one preferred design, meaning that there is still no consistent design of mouse.

Trackball is another version of the mouse which can be thought of as an upside-down mouse. A rotating ball is used to move the cursor on the screen. It is generally used in places where a suitable desk area is not present. It can easily be mounted on any platform and users can use it without needing much space. Museums, exhibitions and similar public platforms are suitable places to use such devices.

Another well-known device is the joystick. It was initially used for games in computer era. Later, designers also adapted it for use in computer based simulations. It has several variations in terms of design. It is generally used for precise positioning of the cursor for various types of applications. Several buttons can also be added to assign dedicated tasks.

Directional pad is another gamers' choice. There are generally four direction buttons and users click on them to manipulate the movement of an avatar on screen. It was widely used in computer games before analog sticks emerged.

Analog stick is a short version of a joystick generally located on gamepads and ergonomically located at the position of the thumb. It is an alternative to the directional pad and it can provide analog input to the system.

Trackpoints are used on laptop computers to move the mouse cursor on the screen. It is embedded in keyboards for easy usage with a finger. It is mostly preferred for word processing applications where lots of change between mouse and keyboard occurs. It is not widely used nowadays because of the emergence of touchpads.

Laptop users like being mobile and their input device preferences are likewise. Instead of using a mouse, they prefer using touchpads. Touchpad is a device that provides a small area to touch and move the cursor simultaneously on the screen. Touchpad movements map to screen movements. If the users can make fast movements on the touchpad the cursor moves faster on the screen. If users make small movements on touchpad, then cursor moves slower and more accurately on the screen. It is generally built-in below the keyboard where users can easily reach it without moving their forearm.

Another touch sensitive surface is the graphics tablet. It is generally located on a desk separate from the computer. It is easier to use it since it is not vertically mounted and users can rest their arm while using it. Another appealing feature of is that it can be used with a separate stylus. Graphic artists commonly use these devices with high precision as it affords better usability. It is generally used with drawing programs.

It can be said that the mouse is the most used indirect-control pointing device historically. However, nowadays with the rise in laptop usage, touchpads are widely available and their usage rates are becoming identical to the mouse's usage rates.

2.2.2.4. Other Pointing Devices

Pointing devices became very popular and successful. On the other hand, user needs are becoming more complex every day. Since standard pointing devices are not capable of meeting some of these needs, new designs and solutions emerge. Some of these successful pointing devices are mentioned below.

Multiple-touch touchscreens are popular and widely employed on many devices. Touchscreens can be set up to allow users to use both hands or more than one finger at once (Han, 2005). It is also possible for multiple users to use multiple-touch touchscreens simultaneously on a shared surface (Carpendale, et al., 2006). These devices are becoming more popular, especially for commercial applications. Microsoft Surface and TouchTable are examples of such multi-touch surfaces. Multi-touch touchscreens enable different modalities for input. An example is that more precise item selection can be done by using two fingers (Benko, Wilson, & Baudisch, 2006). Accordingly, the cursor is located between two fingers and users can adjust its location by moving the fingers apart or towards each other. It is possible to identify which user touched the screen with certain technologies like the Circle Twelve's DiamondTouch. Horizontal table-top displays enable users to stand around them and use them collaboratively. Some real objects can also be used with these devices for a better immersive effect. One step further can be to use stereoscopic displays or head-mounted displays and interact with pseudo 3D objects virtually on such surfaces. Another successful multi-touch implementation is seen on the screens of mobile devices. Since the introduction of this technology by iPhone, gestural interaction and overall usage of mobile devices have increased significantly.

Eye-trackers are used to obtain data where the user is looking at any given time. This process is accomplished by continuously capturing the pupil of the user with image recording techniques. Even though it can be used to command computers, this technology still has some unstable usage issues which limits its application.

Multiple-degree-of-freedom devices provide dimensional data to a system, particularly when position and orientation data needs to be captured. They are useful for the control of objects in three-dimensional environments. While this type of interaction seems promising it remains slow in practice and has low precision. While such devices can provide better virtual reality than any other input system, to simulate a good virtual reality experience at least six-degrees-of-freedom is required.

Data gloves have also been developed as three dimensional data sources for computers. They generally measure angles among several control points located according to the fingers and joints. Typically, relative movement among each finger is transferred to the system. They are not precise, remain expensive and are thus not yet widely available.

Image processing techniques have also been recently introduced to capture three dimensional body movements. Xbox Kinect collects body gestures for gaming that is fairly accurate. Several applications using such devices emerged in the recent years and some are beneficial for people with disabilities.

Several sensor based data collectors also provide input data for systems but their data has to be collected and translated to meaningful input. These sensors vary from motion detection based sensors to light sensors and such data is used for pointing purposes.

2.2.3. Input Devices for Large-Size Screens

Input devices used for large-size screen systems are discussed in detailed in a study by Ardito et al. (Ardito, Buono, Costabile, & Desolda, 2015). This found that systems equipped with large displays adapt several innovative interaction modalities to engage people as much as possible. Interaction occurs in 4 different modalities for large-size screen systems. These modalities are touch, external device, tangible objects and the user's body. The study reported that 57% of the surveyed papers described their interaction as touch, 34% of surveyed papers described their interaction as external device, 21% of the surveyed papers described their interaction as tangible object and there are several studies that describe their interaction as a part of the body interaction. A number of different technologies are used to generate touch interaction modality. They include infrared emitters and an infrared camera (Schöning, et al., 2008); ultrathin overlay placed on the visualization surface (FlatFrog, 2015; PQLabs, 2015); and ultrasound emitters and sensors (Ashdown & Robinson, 2004). Our proposed test system includes such a solution whereby an infrared camera system is placed on a large standard display. Even though stated in Bellucci et al. (Bellucci, Malizia, Diaz, & Aedo, 2010), there are no standards, paradigms, or design principles yet for remote interaction with large, permanent displays; additional devices are widely used with large-size systems. It is not clear yet which method is best for interaction on large-size screen systems, however some issues like privacy require additional devices to be included in the system. She et al. (She, Crowcroft, Fu, & Li, 2014) discuss how the integration of mobile devices with interactive displays allows useful information to be instantly delivered to audiences for effective and informative advertising and the privacy issue is discussed in this concept. Another modality discussed in the study by Ardito et al. (Ardito, Buono, Costabile, & Desolda, 2015) concerns tangible objects and this approach is referred to as direct manipulation throughout our study. It is accepted as part of touch interaction. The last modality is explained as the body in the study of Ardito et al. (Ardito, Buono, Costabile, & Desolda, 2015) and there are interesting findings. According to this, a technology proposed by Schmidt et al. (Schmidt, Müller, & Bailly, 2013) enables the system to follow the person walking in front of the system and makes the content visible near the person. Another study by Bellucci et al. (Bellucci, Malizia, & Aedo, 2014) categorizes the gestures provided to the system. These studies are very valuable; however, these technologies do not support collaborative usage principles, thus are not covered in our tests.

Our system is based on touchscreen interaction for pointing purposes. We have preferred multi-touch touchscreens to enable simultaneous usage by collaborative users. This type of interaction enables users to directly manipulate data on the screen. Users do not need to keep track of their cursors on the screen since there is no indirect interaction between the system and the user. Another reason for not using indirect pointing devices is that they require a physical location. For example, a mouse needs to be placed on a horizontal surface that is sufficiently located to enable users to control the system. Our system and similar systems do not generally provide such surfaces. Users are close to the screen most of the time and this prohibits the viable installation of a mouse. There are also several users using the system simultaneously and collaboratively. It is easier to directly interact with the on-screen elements in such situations. If there are more than one pointer on the screen, it becomes difficult to keep track of the one that belongs to any one user - thus again using indirect controllers is a better solution. Multi-touch is also necessary since there are several users and they touch the screen at the same time.

2.3. Display Technologies

Displays are the main output devices of computers whereby users receive feedback from a system. Display designs and characteristics vary according to physical dimensions, resolution, color array, luminance, contrast, glare, power consumption, refresh rate, cost, reliability and depth. Besides design differences, there are a number of usage differences that affect the variety of display devices. Portability, ubiquity, simultaneity, privacy, saliency and collaboration are the usability issues that affect display device variety (Raghunath, Narayanaswami, & Pinhanez, 2003). Portability and privacy characteristics are the main characteristics of mobile devices. Saliency is the main characteristic of advertising displays. Collaboration is the main characteristic of a whiteboard display. These examples can be extended when several other cases are considered.

2.3.1. Display Devices

Early devices used raster-scan cathode-ray tube technology whereby electron beams were sent to the surface of the display and light was created at that position. Thereafter plasma displays were developed, a variation of flat panel technology that used gas to generate the light on the screen. Currently the most widely used flat panel technology is the liquid crystal display (LCD) which uses liquid crystals to generate the light source. Light emitting diode (LED) displays differ from LED-backlit LCD displays in that the light source is a light emitting diode comprised of three main colors. This technology is generally used for very large displays and is often cheaper relative to other technologies. A newer variation is the organic LED (OLED) technology which is much more energy efficient and flexible. We can expect further technological advancements as demand for large screen systems expands.

Other less common technologies worth mentioning include projections and e-ink technology. Projectors use a bulb or LED light source which is projected onto a flat surface where the image is created. Innovative e-ink technology uses no power while still and uses only a small amount of energy while changing the display content. E-book readers use this technology. E-ink uses tiny capsules that are charged with electricity. If black ones are charged, they move away from the diode and become visible to the users.

2.3.1.1. Mobile Displays

Mobile devices and related technologies have become significant tools and are of significant importance in healthcare, communication and commerce and industry. With the introduction of such devices it was possible to differentiate them according to their intended usage (Ballard, 2007). These divisions were work related usage devices, those related to entertainment, communication related, and targeted usage devices for performing a limited number of tasks reliably. Mobile devices were used to complete brief and routine tasks. Initial designs were optimized for small routine tasks. However, in the recent years this trend has changed and devices have got smarter and capable of being used to perform a much wider variety of tasks. This is visible in the exponential expansion in the number and capabilities of applications that have been developed for use on mobile devices. Such applications are calibrated for mobile displays which have also been rapidly enhanced in terms of screen resolutions, precision and size, in parallel to advancements in processing power and system capacity. Developments in hardware have also lead to variations in design, development, and new strategies for interaction and user interface.

A number of challenges exist for the mobile user where small screens limit the content that can be displayed. Poor readability is also an issue. Mobile devices are used indoors and outdoors, imposing variations in light density that affects vision. Designers have responded by trying to solve these problems in a variety of ways. These include adjusting content according to screen size, using large fonts to improve legibility and enabling text to be scrollable.

Web page designs for computer displays are not suitable for mobile devices as they can include a number of images positioned anywhere on the web page. High resolution areas are problematic on small screens. Website designers responded by tailoring their content for optimal display on the screen sizes and devices used by people accessing their content. Web editions have therefore had to evolve to provide better service and accessibility to their users. Today's web content therefore tends to be less dependent on menu interaction, automatically optimizes the display of the content according the screen resolution of the user's device, and tend to prefer vertical as opposed to horizontal scroll based navigation. Other developments lead by the mobile device user domain include summarizing text content, data suppression and the use of compact overviews.

Mobile users generally use one hand for interaction while holding the mobile device in the other. Usually the thumb is used for interaction. User interfaces are also being specialized. UI elements are put together to decrease the gap between them and allow users to easily interact with less effort. However, the biggest problem is that designers have to create suitable solutions for different type of devices which have different screen size, input method, processing power and other differentiations.

2.3.1.2. Head-Up and Helmet-Mounted Displays

Head-up displays are primarily used in vehicles. They basically project the content onto the windscreen of the car where a partially silvered surface and enables the image to be visible to the driver, who consequently can read the display without having to take their eyes off the road.

Head-mounted displays or helmet displays are physically worn by their users. They display information to both eyes on very small surfaces that are located close to the eyes. This means that the displays remain visible when the user turns his/her head. This turn event can also be used by the system to update the content shown to the user. The virtual image is recalculated and shown to the user, creating the effect of virtual reality. The created image cannot be seen by any other user at this time. Resolution is smaller relative to the desktop displays currently available, however significant development of this technology is anticipated. One disadvantage is that each user has to wear a device if they want to interact with the content.

3D glasses are also a promising technology that enables users to see the content in three dimensions shown on flat surfaces. Transparent glasses block selected views to each eye which enables the user to perceive the content in three dimensions on the display.

2.3.1.3. Large Displays

Displays are ubiquitous devices in modern life. They are vital components of our computers and are integrated in our cell phones, large-size displays can display broadcasts and are used for commercials in public places. Future developments may be to use displays collaboratively but for now people tend to require large displays where many users need to share content simultaneously. There are three types of large displays. The first type is a multiple-desktop display that is simple to set up and can be created by home users. Here, several desktop displays are connected to a single computer via a single graphics card. The combined display shows the content as a single view. The second type is an informational wall display that provides a large display area for sharing a common view to several users from a distance at the same time. The third type is an interactive wall display that allows users to view the content at the same time and to interact with it simultaneously. Accordingly, a large display area is also an interaction area for several users. All three types can be combined to create hybrid alternatives.

Large information displays enable several users to see the same content at the same time. Control rooms or similar places are examples of where they are used. Here, common content is displayed to everyone to create a common understanding. Individual users can see details whenever they want on their personal displays. This type of display interaction enhances common understanding of the content and this increases coordination. Large wall displays also enables teams to collaboratively study the same content and create better solutions and decisions for problems.

Wall displays first started as several CRTs built as matrices and content is distributed among them. This method was easily accepted by commercial applications and distributed worldwide. Later on the technology switched from CRT to rear projection. Their resolution, calibration and distance between two consecutive displays have been improved thus resulting in better vision. As these are generally used from a distance, brighter projectors are required. They are often used in open air locations. On the other hand, if wall displays are used as whiteboard applications, higher resolutions similar to desktop displays are required. Projector technology for whiteboard applications is less common and LCD displays are used instead.

In interactive displays, conventional interaction techniques may become inappropriate for collaborative usage. For example, indirect-control pointing devices and pull-down style menus become less useful. New techniques are being developed by designers like freehand sketching and novel menu interactions to enable more fluid interaction. Moreover, if large displays are used by several users at the same time, the large area can even be insufficient. Designers are working on new ways to dynamically interact with on-screen elements and change their scale and location for collaborative usage.

Some whiteboard systems directly use the desktop computer principles. SMART Board application of SMART Technologies, Inc. provides such a system for large interactive display systems. It uses the content from a general purpose desktop computer displayed on a large touchscreen display. Users use direct manipulation to interact with the items. They even provide digital pens to enhance the virtual reality feeling of whiteboards. A soft keyboard is provided to enter text.

Today, interactive large displays provide a good alternative for local and remote collaboration enabling users to record and reuse their brain storming ideas. They also provide new tools for artists and performers to easily create new content. Clearly, large-size screen interaction has become an area of innovation with new challenges and opportunities.

Multi-desktop displays consist of several individual displays but a problem is that there are discontinuities at the joints. Most of the time, combined displays are of different size, shape or resolution. This yields misalignments on the overall setup. Another problem is that since these displays are for personal use, users are generally left sitting in a stationary position. Users have to move from one screen to another sometimes even by standing up and this may disturb them and may lead them to miss warnings displayed at the edges of the display. To overcome such issues, some users prefer to assign a specific display for notifications or similar duties.

Multi-desktop displays are useful for specific applications. Modeling or coding is highly efficient in such environments. Video editing, content generation tasks and timeline related issues also require a large view nowadays. It is also useful if several windows are open at the same time. Side by side comparison is easy on multi-desktop displays. Some empirical tests and studies have found that multi-desktop displays can increase the performance and attention of users. However, simply increasing the number of monitors used in such environments leads to a number of problems that require new strategies and techniques to counter. For example, direct manipulation can be a problem because of distance. Finding the mouse cursor across a number of displays can also be a problem. Focusing and alignment problems are also common with larger display areas. Despite these drawbacks, it is seen that users in a variety of working environments tend to want to install several displays or a single large display.

2.3.2. Display Technologies for Large-Size Screens

Output technology on large-size screens has two aspects which are visualization and setup according to Ardito et al. (Ardito, Buono, Costabile, & Desolda, 2015). The study states that, even though projection technology is used traditionally on large-size screens, the current trend is to use the monitor or panel based structure. Panels are sorted in an array to create a large display. This is also the method that we used while creating the test environment. This setup was discussed in the work by Ten Koppel et al. (Ten Koppel, Bailly, Müller, & Walter, 2012) as a chained display. This setup enabled us to use a vertical large-size display.

In our system, we are using a large interactive display. The technology behind it combines several smaller displays with a multi-touch touchscreen capability. Accordingly, we are able to create a large display out of smaller ones and to treat the overall area as a single display. To enable this, a special graphics card is used. The final image is a high resolution scene. On top of it, an infrared based multi-touch panel is placed and user interaction is enabled in this way. To enable collaborative usage, a large-size screen is necessary. People can see and understand what others are doing at that time and can react according to the feedback. A large-size screen is not only necessary for visual purposes but is also required for several people to interact simultaneously. As explained above, smaller screens are not suitable for several people to touch simultaneously. Only a few fingers can fit on a mobile device screen, whereas several people can easily interact using both hands with virtual content on a large-sized display.

2.4. Interaction Technologies

2.4.1. Usability and Collaborative Interaction

There are various studies covering usability of systems. Nielsen has detailed studies and provides valuable information in his book (Nielsen, 1994) about usability and how usability can be analyzed. He defines what usability is and provides a few ideas for better human-computer interaction. To define whether a UI design is good or bad, Nielsen provided the heuristics for usability testing (Nielsen, 1995). His claim was that heuristic evaluation is comparable to user testing, yet requires fewer test subjects. He come up with a series of heuristics for user interface design and has some useful suggestions on how a good user interface design should be. Such considerations include the visibility of system status, match between system and the real world, user control and freedom, consistency and standards, error prevention, recognition rather than recall, flexibility and efficiency of use, aesthetic and minimalist design, help users recognize-diagnose and recover from errors, and help and documentation topics should be taken into account to do a good user interface design.

Other researchers focused on the large-size size screens employed by in private sector. A design by Elrod et. al. (Elrod, et al., 1992) demonstrated Liveboard. This was a technology to support large-size screen group meetings. In this study, they investigate the use of large interactive displays and remote collaboration. The display in this study could only be used by a dedicated pen and this restricted a single user to use the system and touch only a single point at a time. Even so this study was one of the milestones of collaborative large display interaction. The main aim of the study was to solve the problems of virtual meetings. It was designed as a big white board and users could collaboratively use the same board to express their ideas. This study proved that collaborative usage of large displays is possible and even very useful if more than two people were trying to use the same interaction device or user interface.

Usability studies emerged for large-size screen systems in the following years. Somervell et. al. (Somervell, Wahid, & McCrickard, 2003) reported on usability heuristics for large-size screen information exhibits.

Later it was understood that collaborative usage of such systems was necessary. A study carried by Kim and Snow (Kim & Snow, 2013), explores two aspects of collaborative use on a large-scale multi-touch display: asynchronous access and multiple-input used in group work. They carried out several user tests to identify how collaborative usage can be performed and how successful it is. They provided users with some tasks and wanted them to complete these tasks. According to the usability and performance of the system, users were able to answer some questions. The results show that users can easily lose focus on large-size screens and can miss some details on the far sides of the display. To solve this problem, users need to collaborate and divide the tasks among them with verbal communication. This way it became much easier to use collaboration on large-size screens than trying to accomplish tasks individually. Another result shows that user interface elements should be compact and in the sight of each individual user.

Other studies such as the one by Jagodic (Jagodic, 2011) focus on using large-size screens collaboratively and how to organize the display according to this interaction method. Such studies suggest that, further investments in large-size screen systems will be made and a series of guidelines and principles for creating such systems are still missing.

A study by Shen (Shen, 2006) showed that if tabletop displays are used as input devices and there are several people interacting with them, then it is necessary to create different and collaborative user interfaces for this specific use. Multi-touch, multi-user tabletops are used for the purpose. Users were free to edit the same content simultaneously with their own fingers and the user interface should respond to the users' needs. The devices were relatively small but the idea can easily be adapted to the system we are building since there will be cases where different users have to work in the same small place simultaneously.

Interaction design was investigated several times prior to the introduction of the first personal computers. These studies sometimes focused on hardware and sometimes on software. The introduction of touchscreens gave a further boost to the interaction design concept. In this context Preece et. al. (Preece, Sharp, & Rogers, 2015) stated that the process of interaction design is much more structural and that there are four main approaches: User-centered design, activity-centered design, systems design, and genius design. This suggests that a designer should select one of these approaches if they want their product to be successful. They emphasize that "Even though there are different types of design, there are three fundamental activities that are recognized in all design: understanding requirements, producing a design for requirements and evaluating the design." Such sentiments help us to appreciate that the user is central to interaction design. Thus, for successful interaction, the three fundamental activities of design are extended to include an activity of prototyping so that users can interact with the design. This study also tells us to first handle the physical design. After doing the initial physical design, we have to identify user needs in a formal manner.

Shneiderman and Plaisant (Shneiderman, 1992) discuss designing the user interface for systems and offer an approach that formalizes the process of designing the user interface. Their study collected several good approaches and heuristics and combined them to generate guidelines, principles and theories. Their broad guidelines discuss several different setup environments and design issues but do not specifically focus on large-size screens. However, they refer to how to build a complete system. They mention navigating among interfaces, organizing the display, getting the user's attention and facilitating data entry. They emphasize the importance of determining users' skill level, identifying tasks, choosing an interaction style and offer some suggested guidelines derived from user experiences. They also refer to direct manipulation and how to use it in virtual environments.

There are also a variety of non-academic investigations that are relevant to the field. As we aim to set out guidelines and principles for large-size screen collaborative user interfaces, we also found it useful to investigate commercial approaches.

Apple recently declared a series of design guidelines for developers or designers to follow (Apple, 2016). This work is primarily focused on direct manipulation and touchscreens. We can generalize their work in two main topics: the iOS human interface guidelines and the UIKit user interface catalog. This work is important since both sources provide designers with complete guidelines and a tool kit or UI elements to select from. Designers can both follow the guidelines and use the elements from the UI elements at the same time. They cover most topics of human computer interaction related to the iOS development and include guidance on color selection and typography, icons, graphics, and navigation. This level of detail is significant since most iOS apps are similar and the market is very competitive. The Apple example is important in UI design since they created a disruptive technology for the industry.

Microsoft also released user experience guidelines for Windows (Microsoft, 2016). This is another commercial guideline that can be used while designing user interfaces for users of Windows operating systems. It includes detailed information on UI design principles, how command and control mechanism should be designed, texts, interactions and many more ideas. Windows is important for our study since we will be creating our test bed using this software.

The main purpose of HCI is to improve interaction between devices such as computers and their users. Half a century ago, this concept was limited to human interaction with switches and punched cards for the entry of commands. Computer response was simple with the output given via lights or line printers. With the development in speed and memory of computers, much faster and more direct interaction was sought. Today, interaction between users and computers is much more direct, effective and rapid. Now we have the mouse, keyboard, acceleration sensors, touchscreens and several interaction methods that can directly communicate with computers enabling us to directly manipulate an object generated by a computer. We even have speech communication, writing surfaces and an expanding array of solutions driven by users and advancements across a range of technologies.

2.4.2. Usability and Collaboration for Large-Size Screen Systems

Ardito et al. (Ardito, Buono, Costabile, & Desolda, 2015) report that collaborative usage goes back to early 1990s, however there remain significant gaps in our knowledge of the field. Large-size interactive screens opened new and interesting issues for discussion and more empirical evidence is needed. Bellucci et al. (Bellucci, Malizia, & Aedo, 2014) report on the creative arts multiuser experiences with large interactive displays. They found that large-size screens have a wide usability area suitable for applications in shopping malls, museums and libraries and other multi-user environments. They suggest that, multi device collaboration may be added to large-size screens to enhance collaboration. Besides multiuser, multi-touch is also discussed in the study and the authors note that it is difficult to understand the owner of the input on multi-touch systems.

A more recent study by Lanzilotti et al. (Lanzilotti, Ardito, Costabile, De Angeli, & Desolda, 2015) reveals the results of a collaboration study about large-size screens with pupils. This study focuses on human behavior of large-size screen collaborative usage. They found that, device setup, simultaneous use actions and application purposes are important for collaborative use, and users of large-size screens eventually start to communicate and collaborate to overcome a problem on a public area. Cahill (Cahill, 2014) defines collaboration and communication and their difference with communication the passing of ideas from one party to another, and collaboration the process of solving problems together using communication. With this in mind, we focused on collaborative usage of large-size screens.

There are also other recent studies that focus on large-size screen popularity. A study by Michelis and Müller (Michelis & Müller, 2011) put a large-size screen in a storefront and collect data of user behavior. The study shows that even though users do not have any specific background with large-size displays, they generally tend to use it naturally by trying to command it with body gestures. This study is important since it gives insights of how people learn to use large-size screens and how natural interaction is important for large-size screens. Similarly, our initial design is built on the philosophy that natural interaction should be the base interaction model for large-size screens.

CHAPTER 3

RESEARCH METHOD AND SETUP

This chapter discusses research method throughout the study, hardware setup which the initial trials and final tests are executed on, initial gestures and initial interaction menu. In the first section, research methods in the area of human-computer interaction are identified and explained. In the second section, our hardware setup and the collaborative large-size screen is described. In the third section an initial gesture library for the collaborative large-size screen is defined and discussed. In the fourth section, an initial list of UI elements is provided.

3.1. Research Method

To start the study and continue systematically, we searched the literature for a review of HCI research methods. Kjeldskov and Graham (Kjeldskov & Graham, 2003) previously reviewed the literature for HCI interaction and grouped them according to the research methods used in each study. Their results show that, researchers tended to use the same research methods for similar tasks. It was reported that the majority of studies completed in the field of human-computer interaction used applied research for engineering purposes and lab experiments for evaluation purposes. Survey methodology is also widely accepted among the researchers. Wynekoop and Conger (Wynekoop & Conger, 1992) state that "Applied research builds on trial and error on the basis of the researchers capabilities of reasoning through intuition, experience, deduction and induction. Typically, the desired goal or outcome of the research process is known in terms of requirements on some level of abstraction, but methods or techniques for accomplishing this outcome are unknown and thus sought through applying potentially relevant research." Laboratory experiments enable researchers to test something under controlled environments and are generally used to test more quantitative data where results can be collected in terms of ratios, interval or ordinal values. Survey research on the other hand, is important to gather data from users on qualitative topics. User centric design is important in recent human-computer interaction systems and survey methodologies are widely used to develop and evaluate such systems. We have followed a combination of the three methodologies.

To create efficient interaction on multi-touch large-size screens to enhance collaboration, designers need to provide effective HCI solutions. A conventional approach is to follow predefined rules and methodologies. There exist several good design solutions, practices, patterns, principles and guidelines for well-known systems. However, such solutions and suggestions are not widely available to designers or academically provided for large-size screen systems.

Large-size screens have different dynamics and ergonomics than regular desktop-size screen systems and mobile-size screen systems and differ in respect to HCI. Existing systems do however offer several successful design solutions. To generate an effective solution, designers need to apply principles and guidelines specific to the demands of the system they are building. As discussed above, such suggestions are not widely available. The purpose of this thesis is to provide such suggestions. Our approach to provide such suggestions is as follows: Initially we have searched the literature for existing technologies and studies. Thereafter, we have set up a prototype system to run a military simulation considered as a serious game to observe the users for usage details. We have created a gesture library and menu based UI elements library for the users to use on large-size screen systems. We have observed the collaborating users and asked them their ideas about the user experience. As the result of these observations and examinations, we went on to define usability differences and similarities among large-size screen systems, desktop-size systems and mobile-size systems. Then we have organized these differences and similarities formally. According to the Shneiderman and Plaisant in "Designing the User Interface" (Shneiderman, 1992), we have grouped these differences and similarities of large-size screen systems into several subtypes. For suitable principles and guidelines that are applicable to large-size screens, we directly adapted that guideline or principle. For the differences, we have built experiments and evaluations to provide new guidelines and principles according to our observations of the experimental system. Simultaneously we have searched the literature for guidelines and principles relevant to desktop-size and mobile-size screen systems. We have used these guidelines and principles to enhance our differences and similarities list and to create our initial guidelines and principles for large-size screen systems. We have then statistically analyzed and discussed our test results. At the final step, we have created a laboratory test environment and a series of tests for evaluating our guidelines and principles and written new ones. The approach is visualized below in Figure 1.

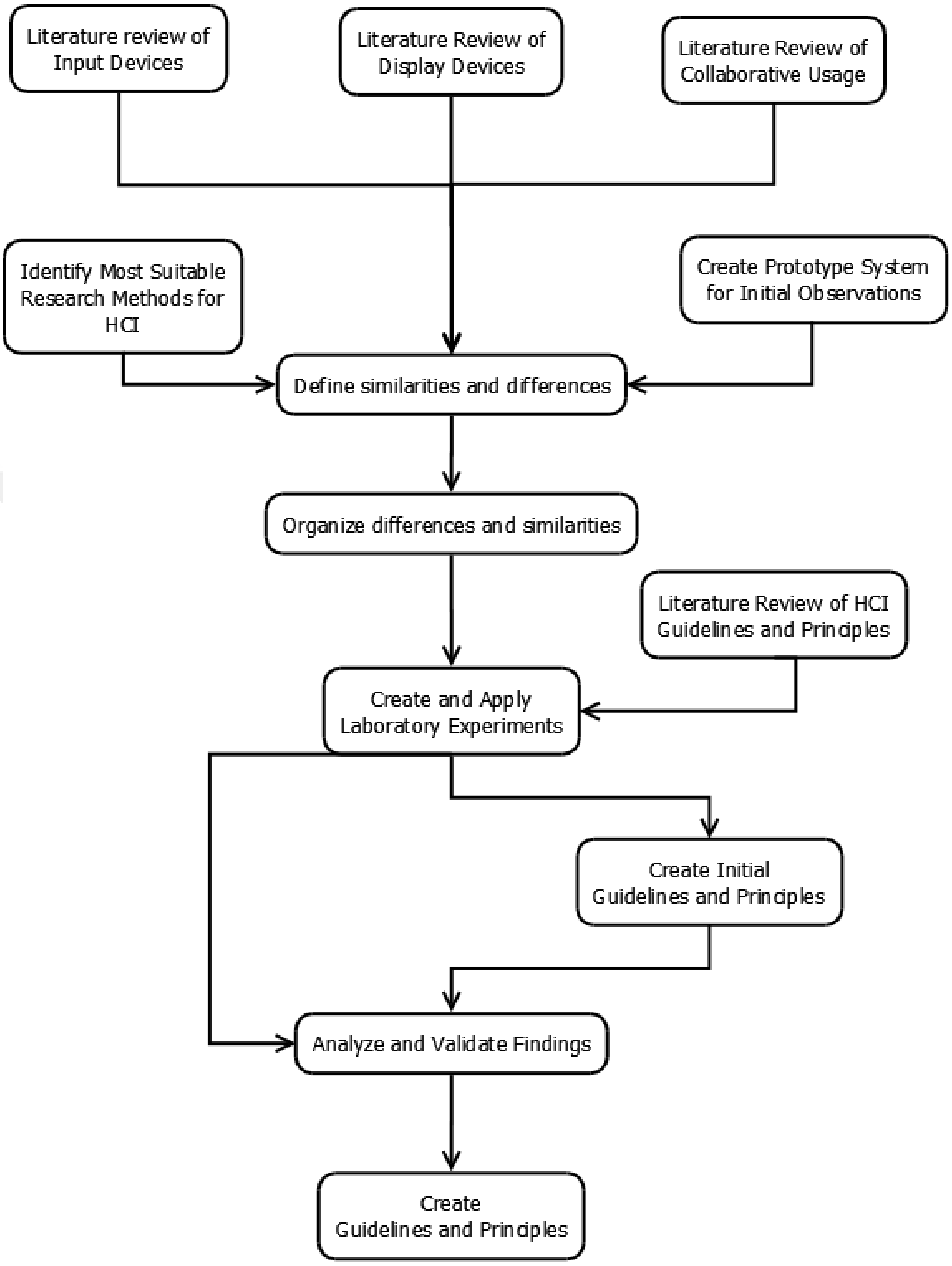


Figure 1: Flow of the Approach

3.2. Hardware Setup

Five 1080p 55 inch LED panels are gathered together vertically. We use one single computer to feed the 5-screen setup. This computer has a 5 out graphics card. This card is able give one single view to the setup as if it is a big screen. An infrared virtual touchpad (frame) is placed on the screens. Frame data is transferred to the device via USB. We converted coming data to screen coordinates. Each single touch data is stacked separately for each finger. Data is transferred to a layer in the processing protocol of our own software system. Construction of the Large-Size Screens is shown in Figure 2.

Figure 2: Construction of the Large-Size Screens

All 5 screens are attached to each other vertically to form the general system. The final product and test environment is shown in Figure 3.

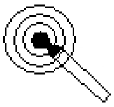
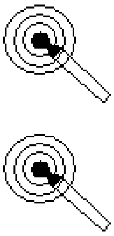
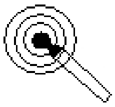
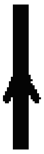
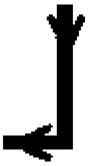
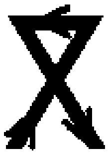
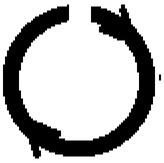
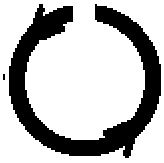
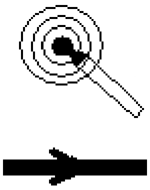
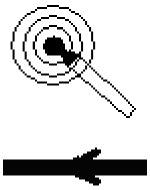
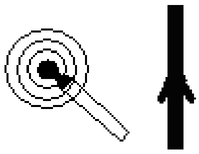
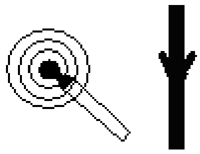
Figure 3: Large-Size Screen

Users can use this setup either individually or collaboratively. Single users can control the whole content individually. Multiple users can both use the system collaboratively or watch a single user to interact with the system as observers. User needs and requirements all differ in each use case. However, a general guidelines and principles collection for designers can be prepared. To do so, initial user requirements and ideas have to be collected. To collect initial user data and observe them while they are using the system, we have provided the users, the hardware, serious game content, initial gesture library and initial UI elements library. Hardware setup is provided as described above. Initial gesture library and initial UI elements library design is given in the following sections respectively.

3.3. Initial Gestures

An initial gesture library is designed and implemented according to the user needs and requirements. These gestures are decided according to the needs of collaborative interaction. We have identified general needs in collaborative interaction such as map movements, command assigning, parameter assigning, information gathering and decided to categorize our gestures in three main categories. The first category is tap-like gestures, the second is single finger gestures and the third category is double finger gestures. Tap-like gestures are mainly tap, double tap and tap & wait. Single finger gestures consist of gestures that are performed with only a single touch.

Double finger gestures are gestures that require two simultaneous touches on the screen at a time. A list of all gestures is shown in Figure 4.

Tap Gesture - GST01 	Double Tap Gesture - GST02 	Tap and Wait Gesture - GST03 	
Right Gesture - GSS01 	Left Gesture - GSS02 	Up Gesture - GSS03 	Down Gesture - GSS04 
Line Gesture - GSS05 	Shake Gesture – GSS06 	Enter Gesture – GSS07 	Delete Gesture – GSS08 
Clockwise Gesture - GSS09 	Counter Clockwise Gesture – GSS10 		
Tap and Right Gesture – GSC01 	Tap and Left Gesture – GSC02 	Tap and Up Gesture – GSC03 	Tap and Down Gesture – GSC04 

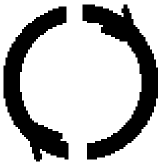
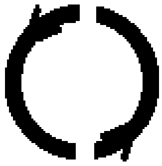
Rotate CW Gesture – GSD01 	Rotate CCW Gesture – GSD02 	Zoom In Gesture – GSD03 	Zoom Out Gesture – GSD04 
Pan Gesture – GSD05 			

Figure 4: Initial Gesture Library

As explained above, we have divided the gesture set into three main categories. The first category is necessary for simple task user actions such as selecting items on screen, assigning target, etc. These simple tasks are suitable for tap-like gestures. On the other hand, since touch screens do not have right-mouse click like capabilities, we have to specify some tasks by assigning gestures to them. For example, delete functionality can be completed by simply performing the delete gestures. Other requirements consist of directly manipulating environment items such as terrain. For those tasks, we have used multi-touch capability of our environment. A two-point zoom gesture or pan gesture directly manipulates terrain or similar items on serious games. A visualization of how touch gestures are performed is shown in Figure 5.

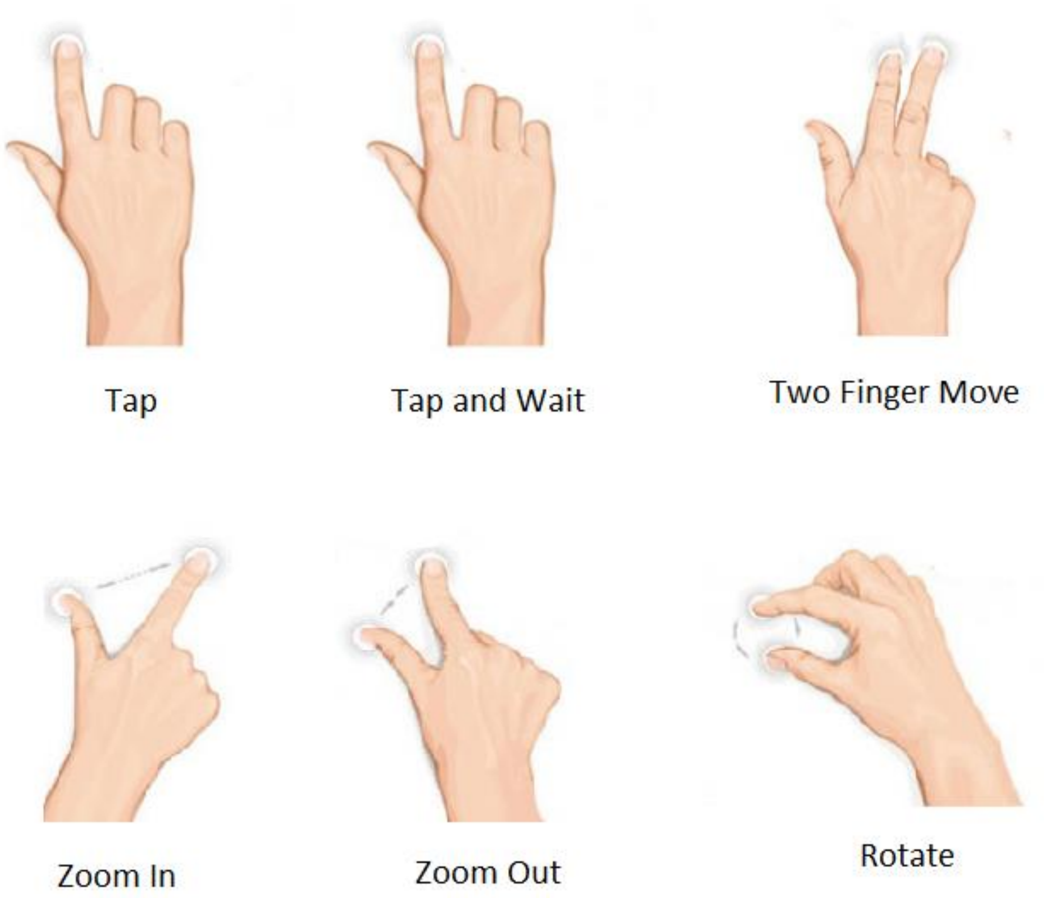


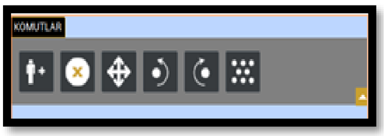
Figure 5: Touch Gestures Visualization

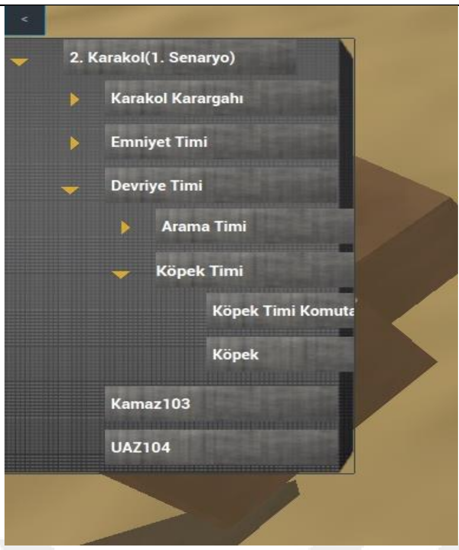
3.4. Initial UI Elements

As expressed in above, a new initial UI library is created for data collection purposes. We have implemented several UI elements to enable inputs via menu interaction and we have categorized those elements. We discovered that large-size screens need different UI elements that should not be too far away from the user. For example, selection menus should be in reach of the user and action menus should be in the center of the screen. These initial UI elements are illustrated as complete in Figure 6.

Figure 6: Initial UI Menu

Main UI elements consist of buttons, lists, collapse-expand items, scrollable items, drag and drop items and a few other controls. All of these have limitations and advantages for large and multi-touch screens. UI elements list can be found in Figure 7.

Regular Button		Must be large enough to enable user to tap with finger instead of a pointer
Small Button		Must be organized in a cellular form to avoid wrong commands

<table>
<tr>
<td>List, Collapse-Expand</td>
<td>
</td>
<td>List items should be large enough again for fingers.

Collapse and expand icons should be shown clearly and must be large enough.

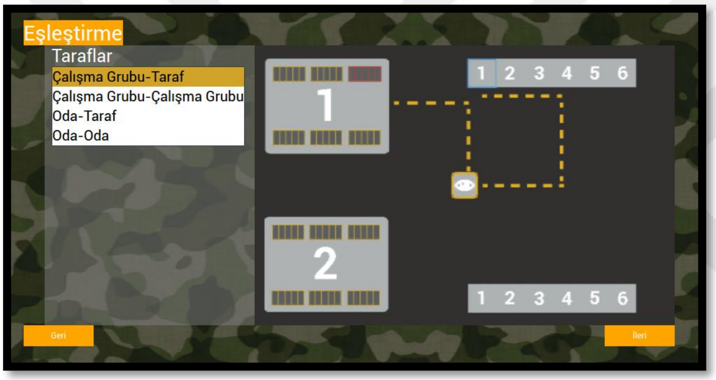
There should not be any tooltip like behavior</td>
</tr>
<tr>
<td>Drag</td>
<td>
</td>
<td>Grab should start with touch and stop with release for drag operation</td>
</tr>
<tr>
<td>Scrollable</td>
<td>
</td>
<td>Scroll should be handled with touch since there is no middle button like behavior in touch</td>
</tr>
</table>

Figure 7: List of Initial UI Elements

3.5. Initial Findings

During initial observations, we found that users have generally similar requirements and comments. Most of the users commented that some parts of the display are easier to interact with and some parts are easier to see and notice. Users generally reported that the lower parts of the screen are better for interaction elements. Middle and upper parts are better for visual and feedback elements. An illustration of readability is given in Figure 8.

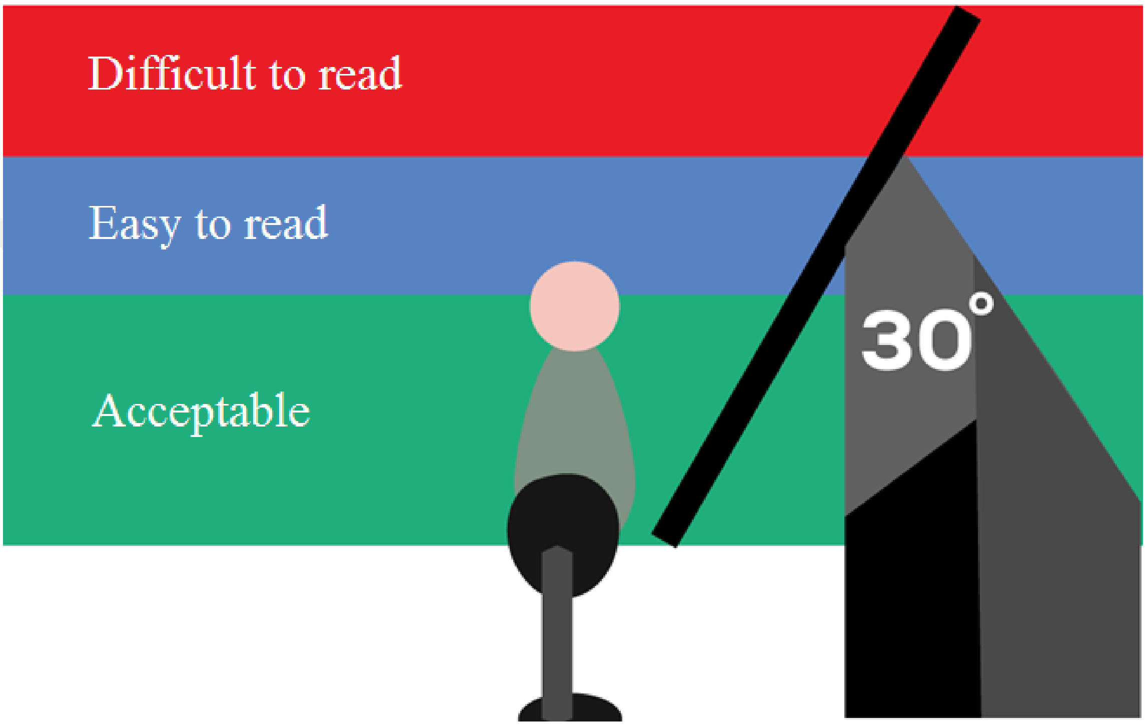


Figure 8: Readability of Large-Size Screen

Touch interaction was seen to be acceptable and gestures made interaction easier. Arm reach distance was accepted as the user's own interaction by general perception. Direct manipulation and menu interaction was mostly used around that area. An illustration of interaction areas is given in Figure 9.

Figure 9: Interaction Areas

Our research discusses usability and collaborative usage findings in the relevant chapters. However initial findings helped us to form and compose basic differences and similarities, and to prepare preliminary guidelines, principles and ideas about the design of large-size screen systems.

CHAPTER 4

DIFFERENCES AND SIMILARITIES

To prepare guidelines and principles, we sought to identify the differences and similarities of large-size screen systems vs. mobile-size and desktop-size screen systems. Details of differences and similarities are given in this chapter. In the first section, our method of defining the differences and similarities and also the summary of all differences and similarities are given. In the second section, detailed information and comparisons among large-size screens and desktop-size screens / mobile-size screens are discussed.

4.1. Summary of Screen Size Related Differences and Similarities in Tabular Form

To identify the differences and similarities of large-size screen systems vs. mobile-size screen and desktop-size screen systems, we have collected usage data from real users of our created system and combined this knowledge with related studies. We used applied research methods to identify these differences and similarities. Applied research was also used to create the gesture library, UI elements and interaction style by assessing user needs. We enabled users to use these initial parts several times and then collected feedback and usage info from them. Then, according to user feedback and our observations, we upgraded or changed our initial proposals. The summary of the differences and similarities is given in tabular format below. Differences are given in Table 1. Similarities are given in Table 2. These differences and similarities are the differences and similarities of respective systems versus large-size screen systems.

Table 1: Differences with Large-Size Screens

Differences		
	Desktop-Size Screens	**Mobile-Size Screens**
Interaction Style & Data Entry	- Mouse, keyboard and other interaction devices are used - a dedicated device has to be assigned to each user - Cursor is easy to find on screen for single cursor	- Single handed touch is possible - One or two finger gestures are common - More than one user cannot hold and use simultaneously - Single on-screen keyboard is provided - Auto complete can be used for single user

	- There is enough physical location to put single mouse and keyboard - Audio and visual inputs can be provided - Multi-touch is not available	- Audio and visual inputs can be provided
User Skill Level	- Users have chance to practice applications several times - Users have experience about similar devices - Users are not expert about the domain - Users do not use the same device collaboratively	- Users have chance to practice applications several times - Users have experience about similar devices - Users are not expert about the domain - Users do not use the same device collaboratively
Task and Goal	- Tasks are designed for single user - Goals can be accomplished by single user easily - Tasks are designed for desktop-size screen dynamics	- Tasks are designed for single user - Goals can be accomplished by single user easily - Tasks can be completed with less powerful devices - Tasks are designed for small size screen dynamics
Navigation thru Interface	- Users can navigate thru applications since no other users exist - Screen is small so each part of the screen is usable for in app navigating - Applications are generally windowed and several navigation occurs among them	- Users can navigate thru applications since no other users exist - Screen is small so each part of the screen is usable for in app navigating
Display Organization	- Every part on screen is easily reachable with mouse for each user - Menus, notifications and similar elements are located arbitrarily on screen - A bottom line menu is always usable for users	- Every part of the screen is visible for all users - UI elements are located according to the single handed handheld usage ergonomics - There are small number of UI elements on screen - Paging principle is applied since screen is too small - Every part on screen is easily reachable - Menus, notification and similar elements are generally full screen
UI Element	- There are specialized UI elements such as scrollable controls which can be used only by one user - UI elements can be dragged or repositioned for easy use - UI elements are not designed for single purpose - UI elements are customizable - Double click and similar controls are more common	- UI elements are not available for multi-touch thus for collaborative use - UI elements are designed for small screens - UI elements can be dragged or repositioned for easy use - UI elements are not designed for single purpose - UI elements are customizable
Feedback	- Sound feedback is used - Haptic feedback exists by mouse and keyboard	- Full screen feedback is used - Sound feedback is used

Table 2: Similarities with Large-Size Screens

Similarities		
	Desktop-Size Screens	**Mobile-Size Screens**
Interaction Style & Data Entry	- There is enough usage area for several users to interact with the system - Dense data can be provided in a short time - All users can easily see and participate in data entry - More than one user can enter data simultaneously	- Both use touch interaction - Direct manipulation is used to provide data - Capable of multi-touch - Gestures are used - Third-party devices are not used - On-screen keyboards are used
User Skill Level	- Users are not familiar with collaborative interfaces - Users use an application for long times	- Users are not familiar with collaborative interfaces - Users do not have technological background - Users start as novice user at the beginning and become expert by using a lot
Task and Goal	- Users are working on the same device to complete the tasks - Tasks need powerful devices - Goals are complex and long-term	- Users can be physically mobile while completing tasks - Tasks can be completed by few interaction events - Goals are well defined
Navigation thru Interface	- In app navigations are present	- Applications are generally full screen - Only one app is active at a time so no inter app navigation occurs
Display Organization	- Each part of screen is in the field of view for multi-user - UI elements can be located arbitrarily on screen	- Menus, notifications and similar elements are located always at same locations - UI elements are not designed to be dragged
UI Element	- UI elements are high resolution and large	- UI elements are suitable for touch interaction and direct manipulation
Feedback	- Windowed feedback is given - Visual feedback is located arbitrarily on screen	- Feedback is always related with the active app

4.2. Categorization of Differences and Similarities

There are several differences and similarities among large-size screen systems, mobile-size screen systems and desktop-size screen systems. Even though the diversity is high, it is necessary to categorize them for making it possible to verify these differences and similarities quantitatively. To formally categorize these differences and similarities, we have searched the literature. According to our research, Shneiderman and Plaisant discuss how to formally categorize guidelines and principles while designing human-computer interaction of a system in their book “Designing the User Interface” (Shneiderman, 1992). This categorization is considered as a basis for categorizing differences and similarities of different systems. These subcategories are given in the following subsections of this section.

4.2.1. Interaction Style & Data Entry Differences and Similarities

4.2.1.1. Large-Size Screens vs. Desktop-Size Screens

Human computer interaction is mostly handled by mouse and keyboard on desktop-size screen systems (Woods, Hastings, Buckle, & Haslam, 2002). Generally, these systems are used for mass data entry and similar processes. Word processing applications can be thought as a reasonable example. These applications are possibly the most used applications on desktop computers (Encyclopedia.com, 2015). This situation yields to the standard usage of keyboard input for the purpose of collection of knowledge. However large-size screen systems are generally used for distribution of knowledge instead. Example for this can be found in museums and exhibitions, where these systems are used to deliver information to the visitors. Users of these systems can reach the required information by entering little or even no data at all. Collaborative environments, which we focus on, have similar input needs too but these needs do not require the kind of dense data entry that would necessitate a keyboard.

During observations and examinations, we were unable to detect any need for mass data entry and typing capabilities made by keyboard except for a few simple numerical data for large-size screen devices. Mouse input is covered independently. According to this, users who are located near the screen, have difficulties finding the mouse cursor on the screen on such a large area. After finding the cursor, the user has to move the cursor to the destination with some effort on a large-size screen. Another mouse related problem occurs when more than one user tries to use the same screen at the same time. When each user manipulates a specific cursor on the screen, they can interfere with each other. There are also physical problems when there is no dedicated surface for the mouse device to be used on and users also have to be mobile to reach each part of the screen. The only visible part of these systems is the screen and rest of the system is located backstage. Finally, large-size screen systems aim to create enhanced virtual reality with high immersion using a large viewing area but third party interaction devices reduces this immersive effect which is not desired for such systems (Maarse, Mulder, Brand, & Akkerman, 2006). Users of such systems are not using these devices for long hours thus the users do not have the time to get tired of using direct manipulation technique on these systems which enhances the virtual reality feeling (Maarse, Mulder, Brand, & Akkerman, 2006). Other interaction devices such as joysticks and virtual reality gloves which provide 3D interaction are not preferred since the visual content is not provided in three dimensions. These devices are not suitable for these systems since they are not practical and they may reduce the simultaneous number of users.

Data entry process is generally provided by mouse and keyboard on desktop-size screen devices. Other than text input, multiple choice and other similar input techniques are also used. Yet most user interfaces are designed according to keyboard usage and applications provide data entry via keyboard functionalities. There are exceptions such as an online food ordering application that requires almost no keyboard input and the user can use mouse clicks to order their meal. On large-size screens on the other hand, data entry is used to receive data instead of providing data and their usage is restricted; thus functionality and usability is specialized accordingly. There are also different interaction methods on desktop-size screens. For example, voice and visual input is provided to the system during video conference applications. Large-size screens are not used for the same type of applications thus there is no need for voice and visual input for these devices. On the other hand, for future use, especially for multi-person voice over IP applications can benefit from such screens. Serious games also require voice data for communication with other users and input techniques for collaborative usage should be considered.

4.2.1.2. Large-Size Screens vs. Mobile-Size Screens

Direct manipulation interaction style has already been used on mobile devices and this interaction methodology is fairly popular for handheld usage (Gartner.com, 2015). In general, the main idea behind the usage of direct manipulation on mobile devices is similar to usage seen on large-size screen devices. Thus, mobile-size screen device interaction does not have huge differences. Touch count is limited on mobile devices. It is also limited on large-size screens but has a larger value. Mobile devices are optimized for single user operations.

Data entry process is difficult on mobile-size screen devices since there is no third party input device such as a mouse or keyboard. The lack of a keyboard which is the easiest way of data input in form of text (Isokoski & Raisamo, 2000) was with virtual keyboards and auto complete functionalities on these devices. On the other hand, on large-size screens, smaller size data is transferred into the system instead of large text values when we consider the usage and needs of such systems. To provide such functionality, users choose from multiple choices or touch to select a function instead of entering text. Apart from text input, users use single touch instead of double click on both systems. Even though direct manipulation is used on both systems, margins and limitations are much more effective on mobile-size screen devices because of the physically available space. Large scale input is used on large-size screens when we consider collaborative usage of several users to avoid confusion. Audio, visual and other types of data are also entered to the system on mobile devices.

4.2.2. User Skill Level Differences and Similarities

Defining user skill levels and types is one of the first goals for a system to be functional. With this knowledge, systems can be created that are much more user-centric and more specific solutions can be provided.

4.2.2.1. Large-Size Screens vs. Desktop-Size Screens

Desktop-size screen device users tend to be more experienced with the applications they are using or get used to those programs since they are using the same applications most of the time. Word processing applications, spreadsheet applications and similar desktop software require mouse and keyboard interaction for data input and manipulation.

4.2.2.2. Large-Size Screens vs. Mobile-Size Screens

Mobile-size screen device users are generally familiar with the general user interface principles because of their prior experience on similar applications. As an example, mobile device users mostly manage contacts, send and receive messages, share picture and video. Thus they can easily learn and use similar applications. Even though they do not have high level technical knowledge, they can have experience on similar devices and applications for content management. Even at novice user interface skill level, users are able to use applications with different functionalities.

4.2.3. Task and Goal Differences and Similarities

4.2.3.1. Large-Size Screens vs. Desktop-Size Screens

Desktop devices are developed and used for data entry, data retrieval and generally data management purposes; and their functionalities and applications are processor-intensive (Encyclopedia.com, 2015). Desktop-size screen devices offer high levels of functionality. Almost everything can be done electronically with these devices. Nevertheless, the situation is not same for large-size screen systems which are expensive, less available for personal use and thus restricted in terms of the number of commercial applications developed for them. Most large-size screen applications are limited and task oriented. It follows that the capabilities of these devices tend to be less than theoretically possible. In general, the difference between large-size screens and desktop-size screens is seen because the tasks on large-size screens are simpler and tasks are discrete and well-defined. A significant difference is seen when several users try to use systems simultaneously. Generally, there is no specific functionality on desktop-size screen devices for collaborative usage and the ones that are multi-user capable are provided by LAN or internet connectivity where more than one device are connected to each other. As an example, multiplayer fighting games are played online while each user connects to a server and manipulates their avatar from a personal computer. On the other hand, large-size screens aim to enable several users to interact with the system simultaneously, complete the tasks collaboratively and display the results publicly. Functionalities are defined according to these needs and tasks are created by targeting these functionalities. Choosing an avatar in a game, commanding this avatar, providing parameter to the command, navigating thru the map and similar tasks are designed and aimed to be completed by several users simultaneously using the same user interface and the results can be seen by each user from the same interface.

4.2.3.2. Large-Size Screens vs. Mobile-Size Screens

Mobile devices are mostly developed and used for ease of use and specialized for the use of applications in different physical locations (SmartInsights, 2015). Even though the interaction style of applications for retrieving data is similar on both large-size screen devices and mobile-size screen devices, their techniques and methods are different. Users of large-size screen devices have much more limited functionality on applications. Due to this, possible functionalities are more limited than mobile devices, for example not having opportunity to easily open a website or surf on the internet. Especially, in collaborative environments, tasks are predefined and shown to the users. These tasks are provided to the system with predefined interaction methods and the system completes the task itself. On the other hand, on mobile devices, users have the option to choose an application from among several choices and to use it for almost unlimited functionality. Mobile device users use their applications several times repetitively. For example, they tend to use messaging functionalities every day. This is not the same for large-size screen users.

4.2.4. Navigation thru Interface Differences and Similarities

4.2.4.1. Large-Size Screens vs. Desktop-Size Screens

Navigation among different applications and in-app navigation thru other parts of the app is important for desktop-size screens. Users of such devices frequently complete different tasks with these devices thus different applications and navigation among those applications should be easy and quick. This process is provided with task bars and application switch screens using keyboard and mouse.

4.2.4.2. Large-Size Screens vs. Mobile-Size Screens

Navigation among different applications and in-app navigation thru other parts of the app is also important for mobile-size screen users. The home button on iOS and the one on Android systems are such examples of these dedicated buttons. With these buttons, navigation among applications is fast and easy. Only one application is full screen and active most of the time.

4.2.5. Display Organization Differences and Similarities

4.2.5.1. Large-Size Screens vs. Desktop-Size Screens

The difference between desktop-size screen devices and large-size screen devices is that, the former have enough space on the screen but mouse and similar interaction devices are used that enable designers to use smaller UI elements. On large-size screens, this cannot be achieved where no precise pointing device is used. Every part of the screen area on desktop-size screen devices is easily reachable because of the usage of pointing devices. Unlike desktops, direct manipulation is favored for large-size screens and the reasons for this are explained several times in this work. However, direct manipulation can make it difficult to reach every part of the screen easily. This results in major differentiations in display organization on large-size screen systems. In contrast, a bottom line menu is typically provided for use on desktop-size screens which enables users to easily reach important programs or functionalities effortlessly.

4.2.5.2. Large-Size Screens vs. Mobile-Size Screens

Mobile devices are designed to let their users to use them with a single hand when display organization is considered (Karlson & Bederson, 2007). These devices are physically small and the area on screen can contain a small number of elements. For example, iPhones can only contain 4 UI elements on screen horizontally. Every part of the screen area on mobile-size screen devices is easily reachable because the screen is small and users can easily reach and touch anywhere on the screen. Small devices do not require a pointer or a third party interaction device like a mouse. Thus the UI elements on the screen should be large enough for a finger to fit in. There should be several UI elements on these devices and these UI elements should fit in the small screen. As a solution approach, designers have chosen to use paging principle on these devices which suggests using several pages to contain similar UI elements and easily change these pages with a simple gesture. This yields navigation among and within applications in a similar manner. On large-size screen devices on the other hand, the much more generous space can mean that users may need to be mobile to reach different parts of the screen arbitrarily.

4.2.6. UI Element Differences and Similarities

4.2.6.1. Large-Size Screens vs. Desktop-Size Screens

There are clear differences between large-size screen devices and desktop-size screen devices in terms of UI elements. UI elements can be too small on desktop-size screen devices because there are mouse pointers on these devices and these pointers are fairly accurate, small and do not block the vision of UI elements. On the other hand, it is not possible to use the same UI elements with the same method on large-size screen devices. Examples of this are checkboxes; they can be too small that they can only be clicked with a pointer with high accuracy. So, it is not easy to click the correct checkbox in an array of checkboxes precisely on large-size screen devices with the absence of mouse pointers. Therefore, these types of functionalities should be handled with different types of UI elements. Similarly scrolling and similar other functionalities should be simulated differently on large-size screen devices since there is no scroll wheel on these devices that exists on a mouse. Right click functionalities are also considered differently for UI elements on large-size screen devices because of the lack of a mouse and right click button.

4.2.6.2. Large-Size Screens vs. Mobile-Size Screens

UI elements on mobile-size screen devices are designed to be large enough for a finger to fit in because of the usability and ergonomics of touchscreen interaction (Park & Han, 2010). This also avoids more than one UI element to be placed under the same finger. Large-size screen devices similarly have the same interaction style thus require large enough UI elements. These devices have enough space on screen and have smaller number of pixels per inches (ppi) thus this situation does not cause a problem. However, matrix style locating of UI elements should be adapted on large-size screen devices. This allows users to estimate which UI element to click on screen with a higher rate. This approach can easily avoid the vision blocking problem of using a finger on touch devices since there is no mouse like pointer on the screen. Dragging, panning, swiping, choosing and similar actions shall start when the finger touches on the screen and finish when the user raises their finger from the screen and this activity should not interfere with other actions. More detailed UI elements are preferred on mobile-size screen devices since ppi on these devices are higher than large-size screen devices (for example, 2015 iPhone 6 plus has a 401 ppi value whereas 2015 MacBook has a value of 226 ppi). Another issue is that, mobile-size screen devices are much more personal and used by only one person at a time, on the other hand large-size screen devices lend themselves to being shared and used collaboratively so UI elements are designed accordingly.

4.2.7. Feedback Differences and Similarities

4.2.7.1. Large-Size Screens vs. Desktop-Size Screens

On desktops, feedback is regularly given as visual and haptic whereas it is possible to give as text based, shape change and visually on desktop-size screen devices. Users also obtain haptic feedback from input devices such as the mouse and keyboard. For example, when a user attempts to click on a key on the keyboard, some feedback is given to the user as to whether the key was pressed or not. Similarly, a user can get haptic feedback when using the scroll wheel on a mouse. Apart from haptic feedback, audio feedback is also typically provided to the user to help them know whether the task is completed or not. On large-size screens on the other hand, both situations may not be available if no mouse pointers, keyboard or third party interaction devices are in use. There is no haptic feedback to users. Clicking on a UI element can be understood only by shape change of the clicked UI element. Similarly using audio feedback is difficult because these devices are used by several people and audio feedback is received by every single user. Thus the results of their commands and tasks are provided with different feedback elements.

4.2.7.2. Large-Size Screens vs. Mobile-Size Screens

On mobile-size screen devices, feedback is provided with windows on screen. UI element feedbacks are shown with shape changes and voices to create a real manipulation effect on a virtual object. Since every part of the screen is within focus area of humans, asynchronized and immediate feedback can be shown as full screen or located anywhere on the screen. On large-size screens on the other hand, it should be shown within the focus area of the user if it is not expected by the user. If a random feedback is shown to the user, the best approach is to define a feedback area and show all user feedback to the user within that area.

CHAPTER 5

GUIDELINES AND PRINCIPLES COMPARISON

In Chapter 5, existing guidelines and principles for human-computer interaction design of desktop-size and mobile-size screen systems are explained. Once these guidelines and principles are described, their relation to the large-size screen systems is discussed. In the first section, guidelines and principles for HCI design of desktop-size screen systems and mobile-size screen systems are given. In the second section, the relation of these existing guidelines and principles for human-computer interaction design to large-size screen systems are discussed.

5.1. Existing Human-Computer Interaction Design Guidelines and Principles

There are several commercial and academic guidelines and principles for human-computer interaction. Industry leading companies such as Microsoft and Apple also provide HCI design guidelines and principles. These have tended to converge with each other and hence designs have also become similar. We have decided to deeply analyze these two companies according to the successes they have achieved in desktop-size and mobile-size devices respectively. Microsoft Windows has reached a high usability rate on desktop-size devices whereas Apple iOS has reached high reputation on mobile-size smart devices. While analyzing these systems, we have used their websites (Microsoft, 2016; Apple, 2016) and other similar sources.

5.1.1. Desktop-Size Screen Guidelines (Microsoft UX Design Guidelines)

Microsoft has a significant history in desktop size computers. It's flagship product Windows is the most used operating system of all times (StatCounter, 2016). Most computer users are familiar with Windows concepts and design. Accordingly, we set out to understand the design principles behind desktop-size systems by looking at Microsoft design guidelines and principles. Starting from Windows 8, Microsoft switched to use a concept called Universal Windows Platform (UWP) (Microsoft, 2016). With this concept, Microsoft aims to combine desktop-size and mobile-size screen device HCI designs.

To make things simpler, Microsoft has created an anatomy of apps from a design perspective. According to this, they divide applications in three parts; which are "Navigation Elements, Content Elements and Command Elements". Figure 10 below shows an example of how parts are categorized.

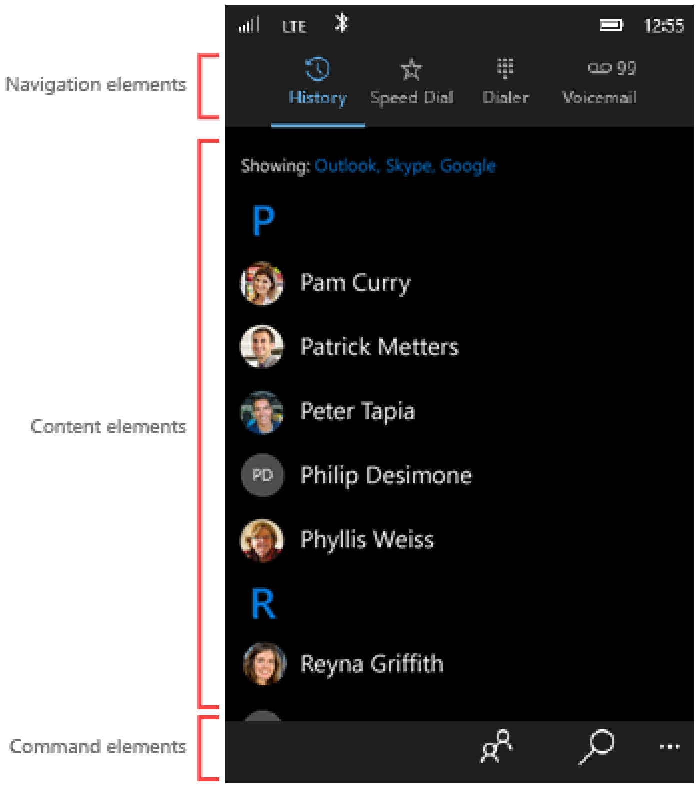


Figure 10: Anatomy of Apps

5.1.2. Mobile-Size Screen Guidelines (iOS Human Interface Guidelines)

Apple iOS design guidelines propose general descriptions for UI element design. They also release their user interface guidelines and UI elements on their website (Apple, 2016). iOS design guidelines and thus choices are important since this operating system has radically influenced mobile-size screen devices and created the phenomenon of the smart phone era (Grossman, 2007). Accordingly, we decided to understand the design principles behind mobile-size systems by looking at iOS design guidelines and principles.

In iOS design guidelines and principles, there are four main types of UI elements grouped according to usage. These are “Bars, Content Views, Controls and Temporary Views”.

5.2. Comparison of Human-Computer Interaction Design Guidelines and Principles

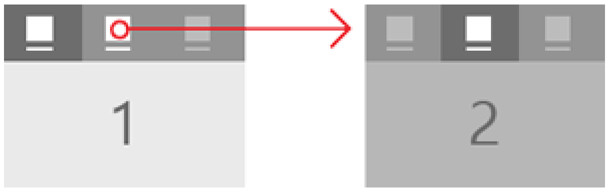
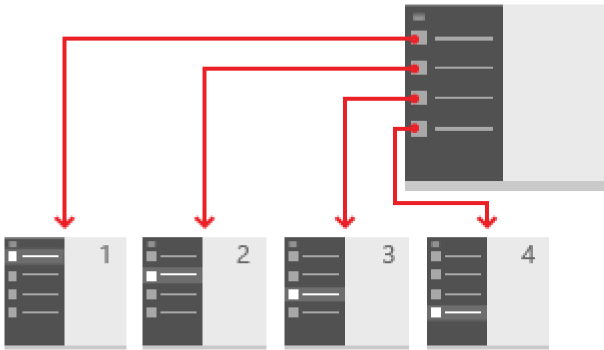
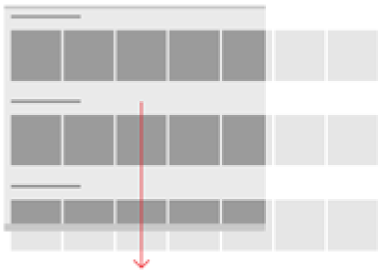
Apple and Microsoft categories and types are similar for both design guidelines and principles. “Navigation Elements” of Microsoft design guidelines and “Bars” of Apple design guidelines are similar. So are “Content Elements” of Microsoft design guidelines and “Content Views” of Apple design guidelines as are “Command Elements” of Microsoft design guidelines and “Controls” of Apple design guidelines. However, the “Temporary Views” of Apple design guidelines do not have a direct similar counterpart in Microsoft design guidelines.

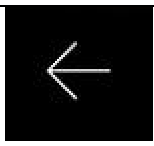
5.2.1. Navigation Elements / Bars

5.2.1.1. Navigation Elements of Microsoft

Navigation Elements of Microsoft generally consist of items that help users to easily navigate among different parts of the software with a single click and let the users know where they are instantaneously. They are simple buttons or similar elements with little info being displayed. A list of navigation elements can be found below in Table 3:

Table 3: Navigation Elements of Microsoft

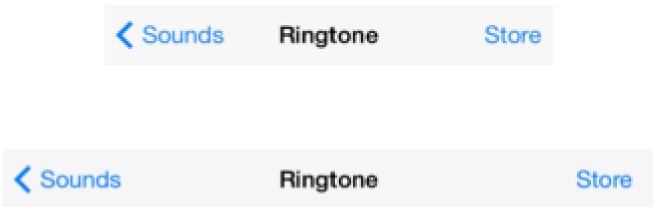
Tabs and pivot	
Nav pane	
Hub	
Master/details	

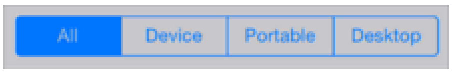
Back	
Hyperlinks and buttons	

5.2.1.2. Bars of Apple

Bars of Apple provide general information on the current status of a system. They span a short area and are hardly visible. It is difficult to see them from a long distance. They seem not to be useful for large-size screen systems. A list of bar elements can be found below in Table 4:

Table 4: Bars of Apple

Status Bar	
Navigation Bar	

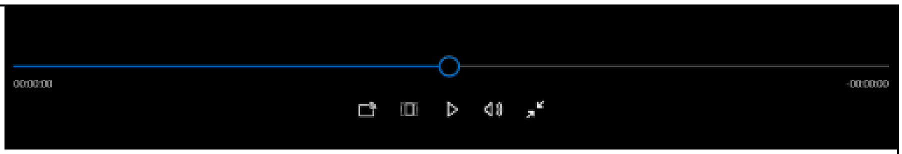
Toolbar	
Tab Bar	
Search Bar	
Scope Bar	

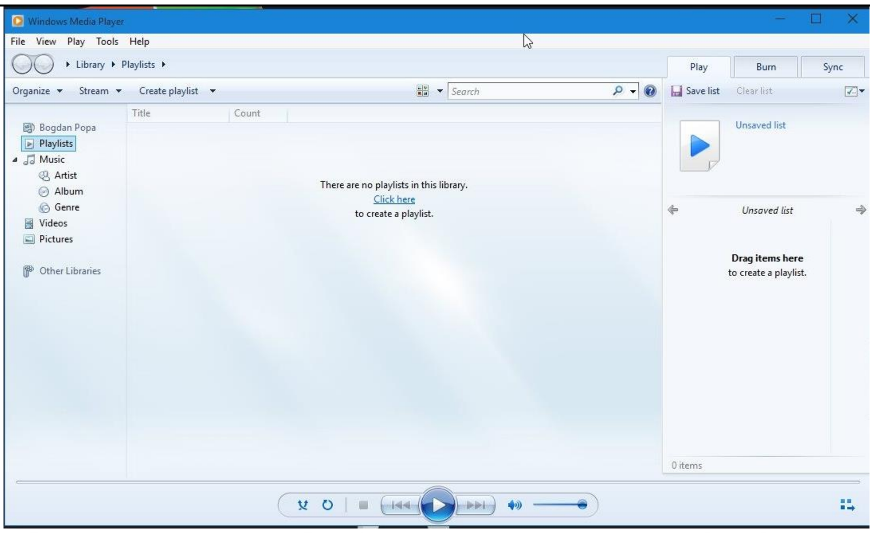
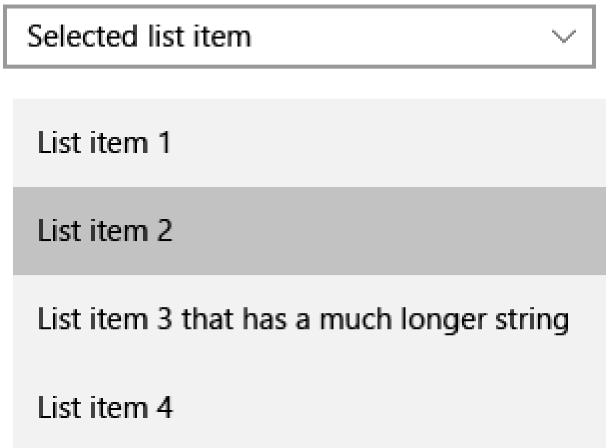
5.2.2. Content Elements / Content Views

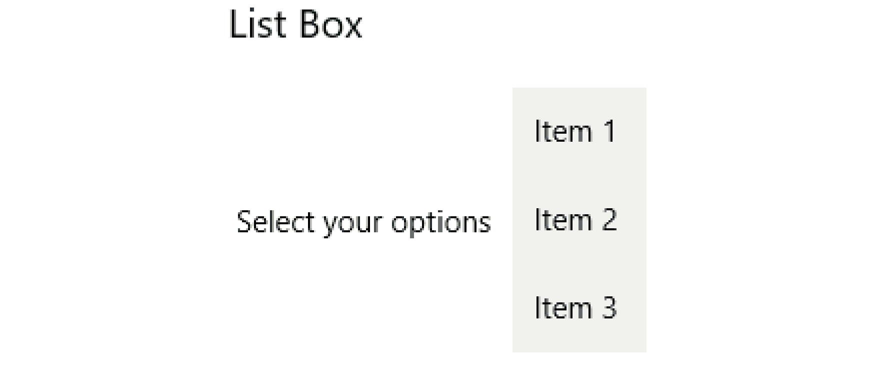
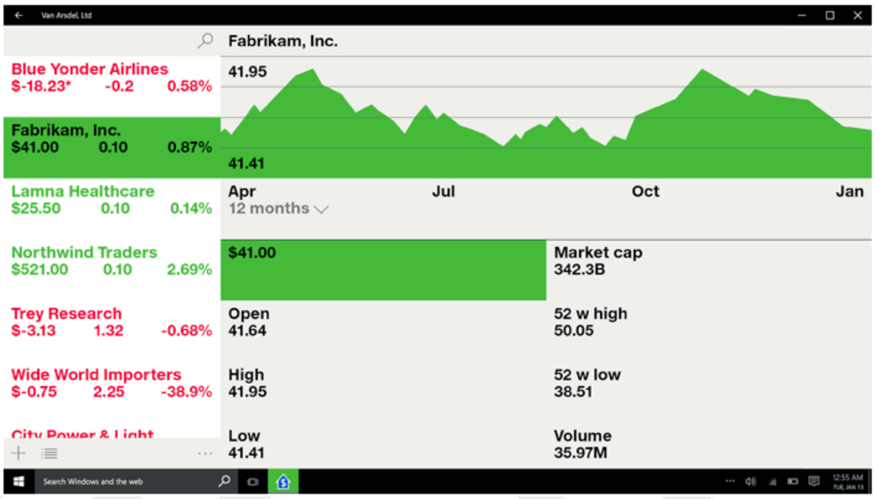
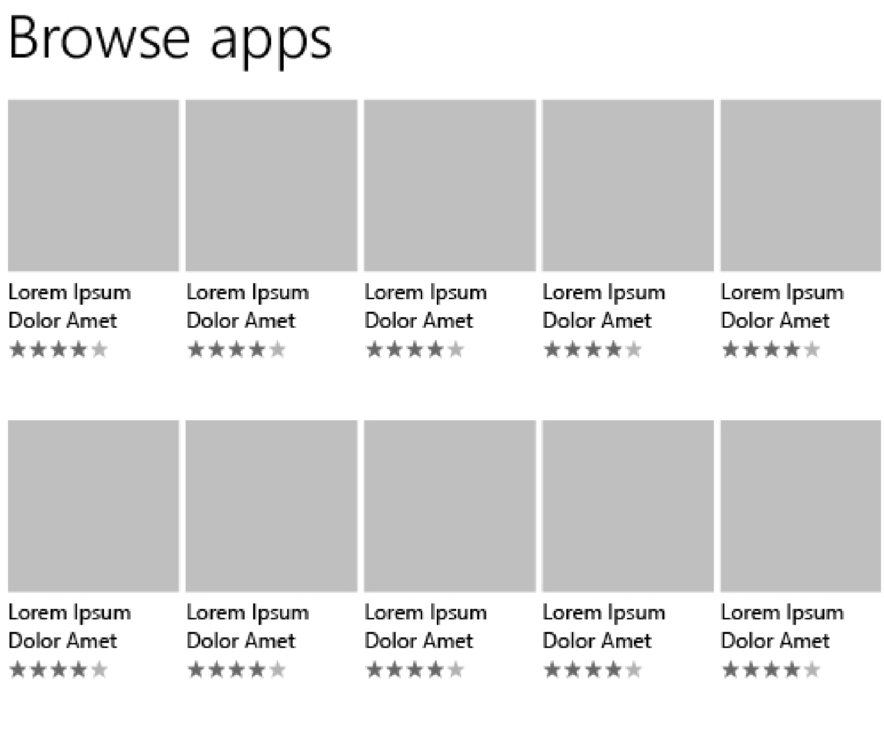
5.2.2.1. Content Elements of Microsoft

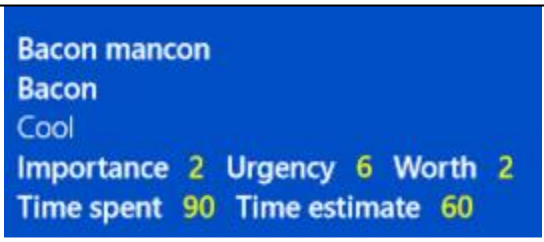
Content Elements of Microsoft are generally used to display the content of the application. They may have different responsibilities depending on the purpose of the application. They are generally visual elements with limited functionality. A list of content elements can be found below in Table 5:

Table 5: Content Elements of Microsoft

MediaTransport Controls	

<table>
<tr><td>Audio and video</td><td>
</td></tr>
<tr><td>Image / Flip View</td><td></td></tr>
<tr><td>Drop-Down List</td><td>
</td></tr>
</table>

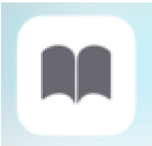
<table>
<tr><td>List Box</td><td>
</td></tr>
<tr><td>List View</td><td>
</td></tr>
<tr><td>Grid View</td><td>
</td></tr>
</table>

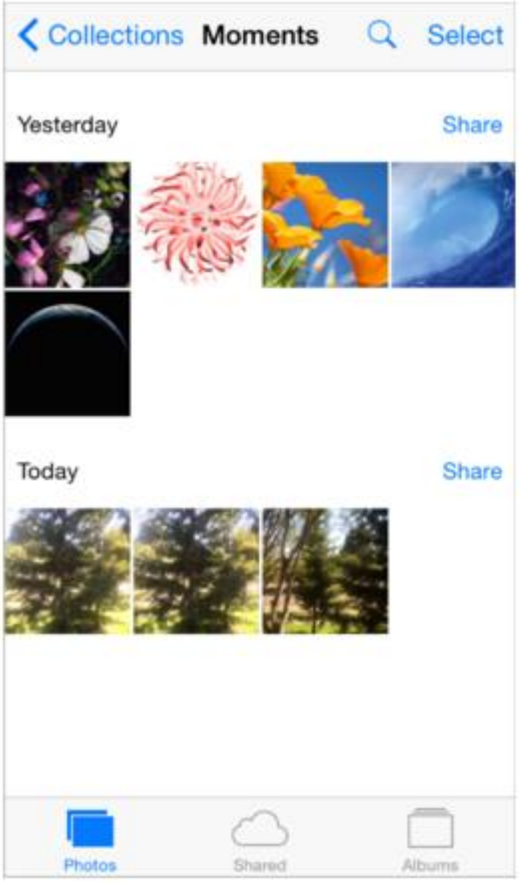
TextBlock	
TextBox	
RichEditBox	 Hi Robert, Thanks very much for your inquiry. Our typical turn-around on articles should be 24-48 hours on business days. If you ever have any questions or concerns about CodeProject, please let me know and I'd be happy to help. Thanks, Sean Ewington The Code Project **From:** submit@codeproject.com [mailto:submit@codeproject.com] **On Behalf Of Sent:** Friday, September 28, 2012 9:23 PM **To:** Submit@codeproject.com **Subject:** Hey, I am wondering how long it takes for an article to become reviewed, and I want to make the license and code of the article Code Projects Open Source. Thank you,

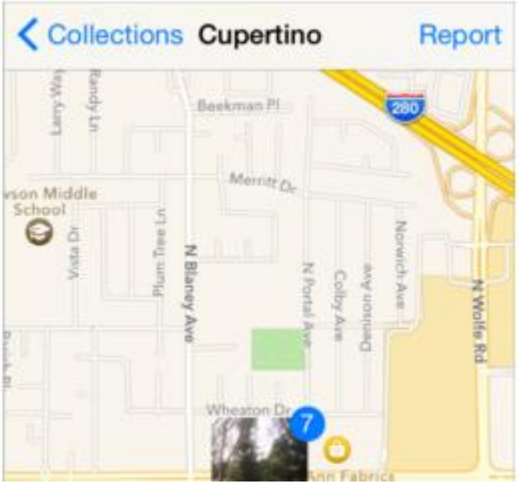
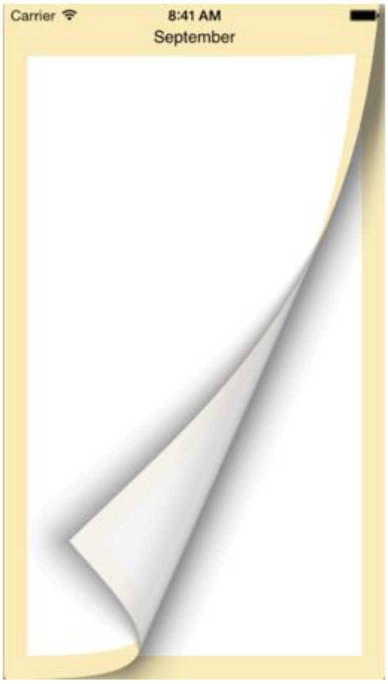
5.2.2.2. Content Views of Apple

A second type of Apple design guidelines consists of Content Views. They are the main parts to provide content for users. They are generally visual elements with limited functionality. A list of content elements can be found below in Table 6:

Table 6: Content Views of Apple

Activity	

Collection View	
Image View	

<table>
<tr><td>Map View</td><td>
</td></tr>
<tr><td>Page View Controller</td><td>
</td></tr>
</table>

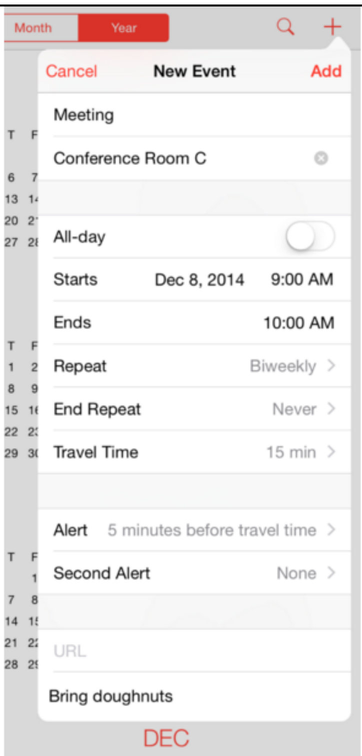
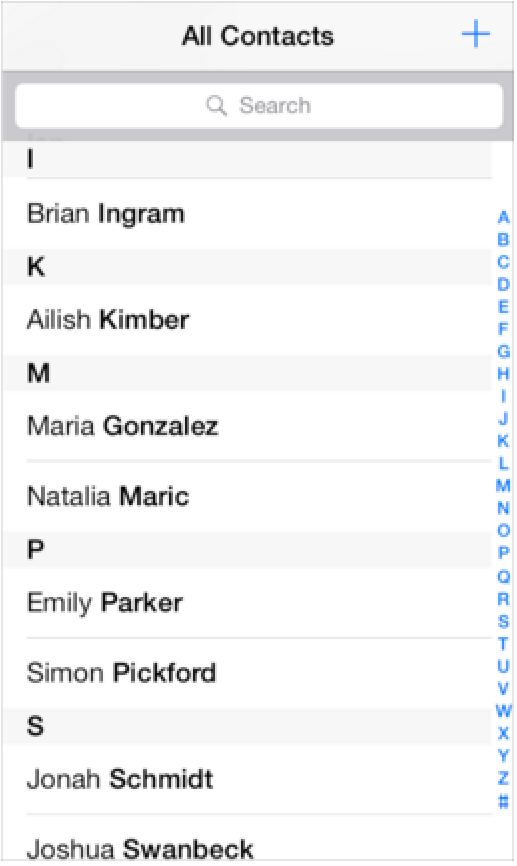
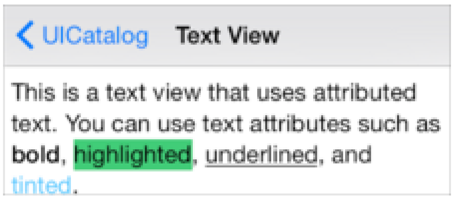
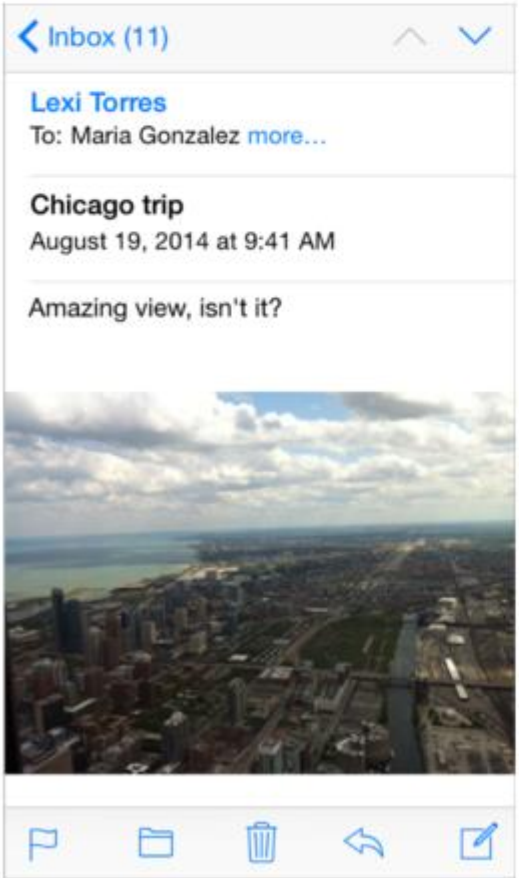
Popover	
Scroll View	

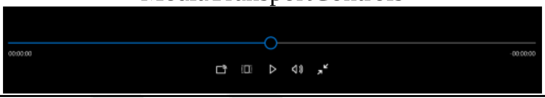
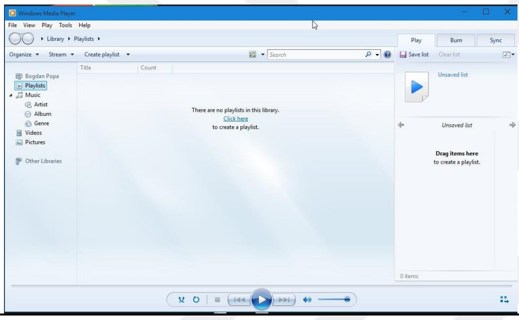
Table View	
Text View	

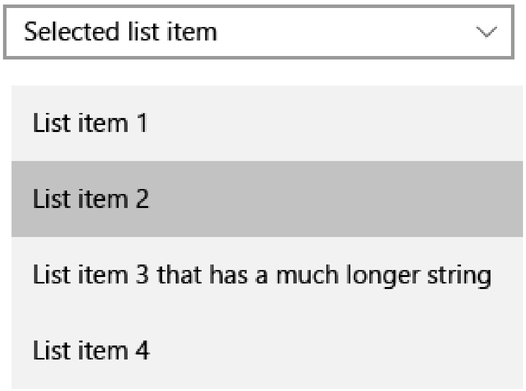
Web View	

5.2.2.3. Differences and Similarities of Content Elements / Content Views

Content Elements (Microsoft) / Content Views (Apple) are used to show necessary information to the user. This is often considered to be the main purpose of large-size screen systems. Even though there are several individual content elements, the most used ones on Microsoft are MediaTransportControls, Audio and video, Image / Flip view, drop-down list, list box, list view, grid view, textBlock, textbox, richEditBox. Similarly, activity, collection view, image view, map view, page view controller, popover, scroll view, table view, text view, web view are the most used ones for iOS. There are similarities among them. Image display visual elements are common for both platforms and also frequently used on large-size screen systems. They have similar guidelines and principle for usage. The only difference can be for locating the image element on the screen. Lists, drop-down lists, list boxes, list views, grid views, collection views, etc. are also similar visual elements in both protocols. They are mainly used to combine several different items and presented to the user in an ordered form. Both protocols provide similar guidelines and principles for this type of element. We also adapted these guidelines and principles and added some suggestions on collaborative usage, as this type of visual elements does not provide accessibility for multiple users. While designing such visual elements, designers should consider collaborative usage and design these visual elements accordingly. Text fields, text boxes and other type of text entry visual elements are also shared in these protocols and similar guidelines and principles. They need to be visible by each user and since there can be several users of a large-sized display, the size of these elements need to be visible to all users. Besides, extra effort is necessary to differentiate the target user of the text being shown. Other visual elements can directly be used on large-size screen systems with their original guidelines and principles. No extra effort is necessary for these items. A side-by-side comparison of Microsoft and Apple UI elements can be seen in Table 7.

Table 7: Side-by-Side Comparison of Visual Elements

Microsoft	Apple
MediaTransportControls 	N/A
Audio and video 	N/A
Image / Flip View 	Image View 
Drop-Down List	Table View



List Box

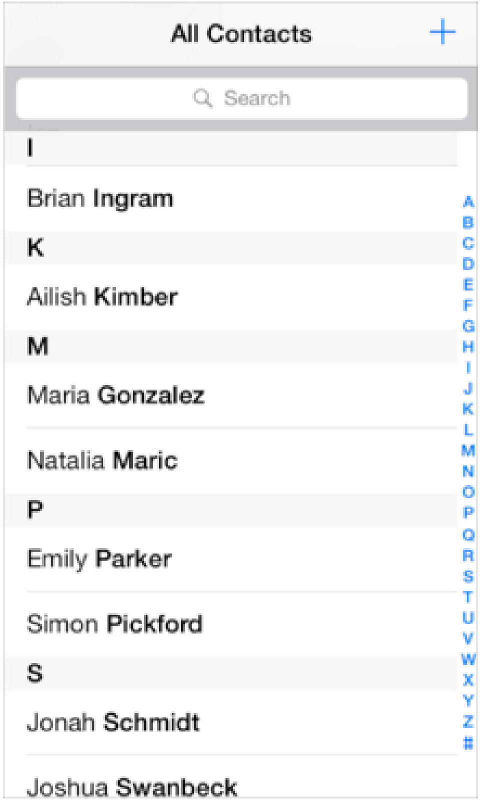
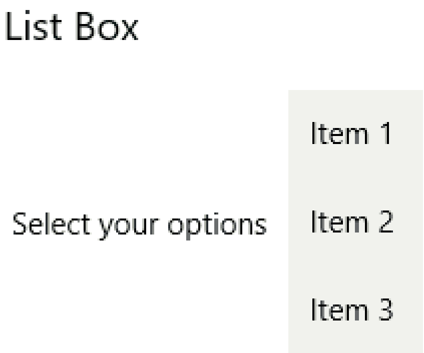
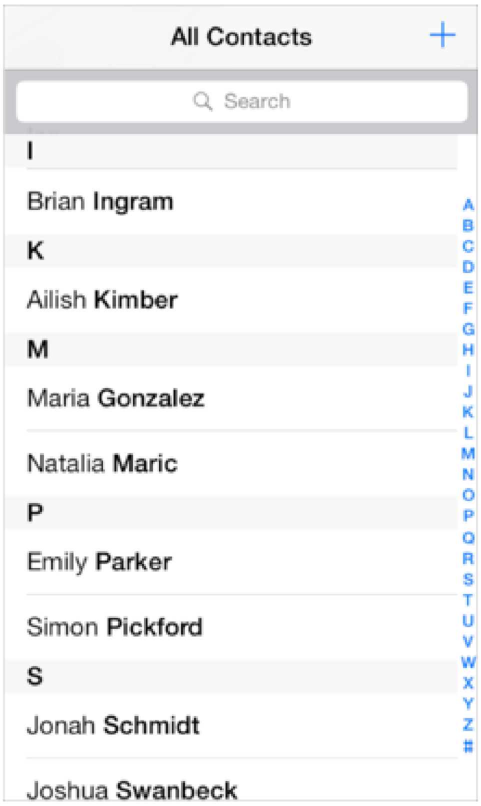


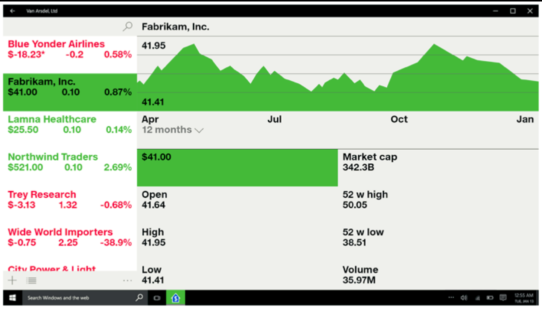
Table View



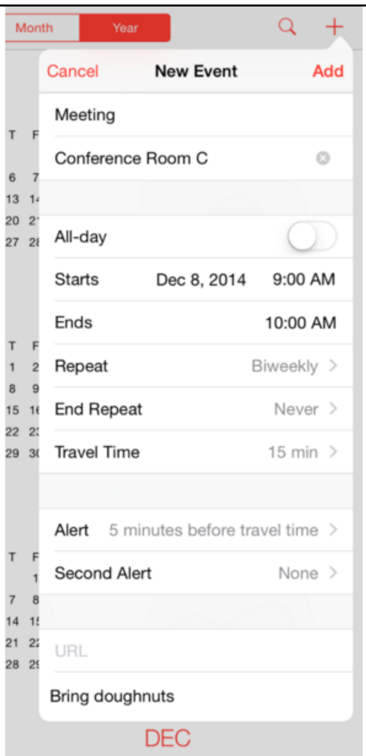
List View



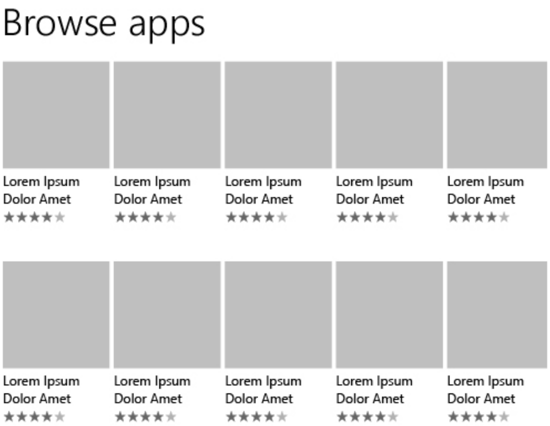
Popover



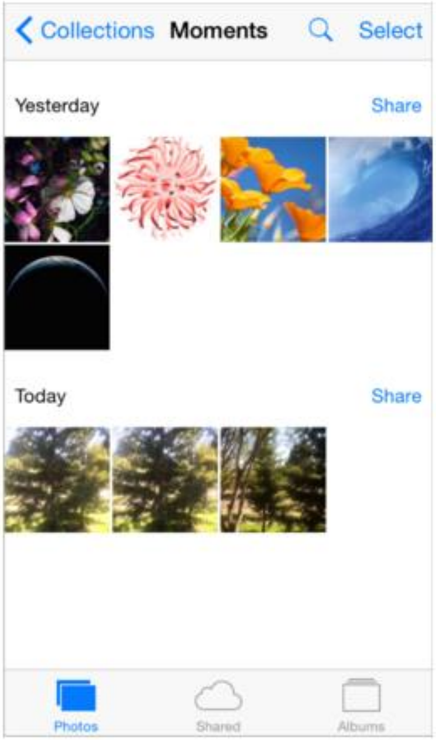
Grid View



Collection View



TextBlock



Text View

<table>
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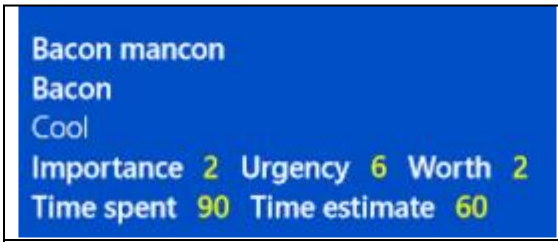
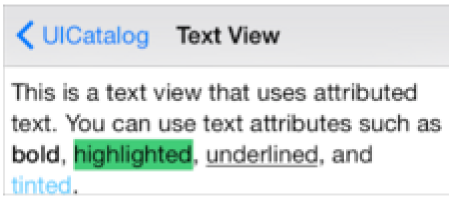
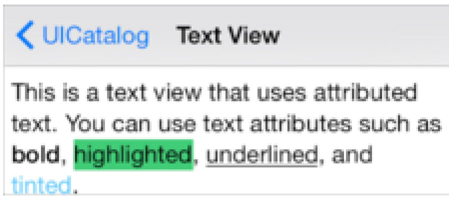
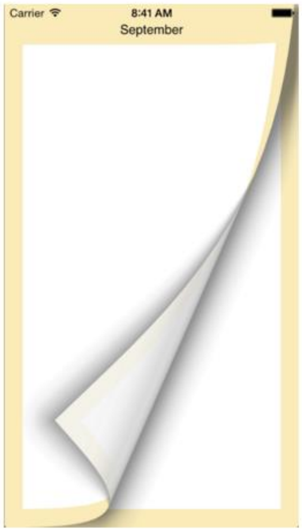
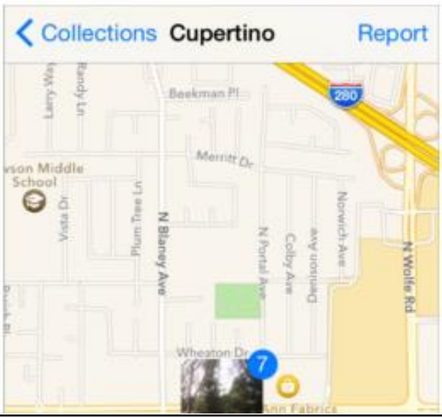
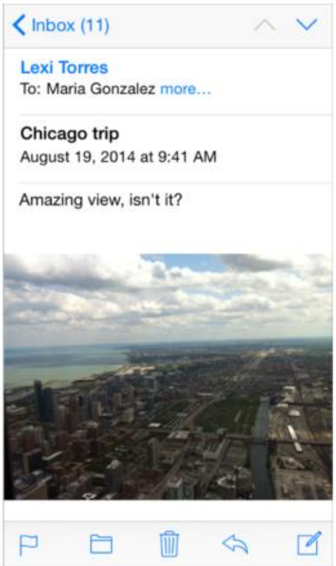
<td></td>
<td></td>
</tr>
<tr>
<td>TextBox
</td>
<td>Text View
</td>
</tr>
<tr>
<td>RichEditBox
Hi Robert,
Thanks very much for your inquiry. Our typical turn-around on articles should be 24-48 hours on business days. If you ever have any questions or concerns about CodeProject, please let me know and I'd be happy to help.
Thanks,
Sean Ewington
The Code Project
From: submit@codeproject.com [mailto:submit@codeproject.com] **On Behalf Of Sent:** Friday, September 28, 2012 9:23 PM
To: Submit@codeproject.com
Subject: Hey, I am wondering how long it takes for an article to become reviewed, and I want to make the license and code of the article Code Projects Open Source.
Thank you,</td>
<td>Page View Controller
</td>
</tr>
<tr>
<td>N/A</td>
<td>Activity
</td>
</tr>
<tr>
<td>N/A</td>
<td>Map View
</td>
</tr>
<tr>
<td>N/A</td>
<td>Scroll View</td>
</tr>
</table>

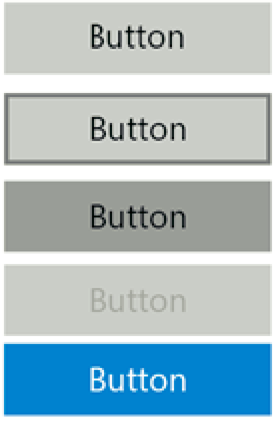
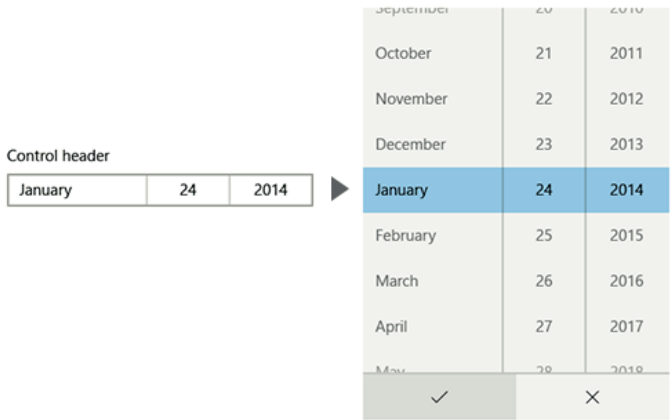
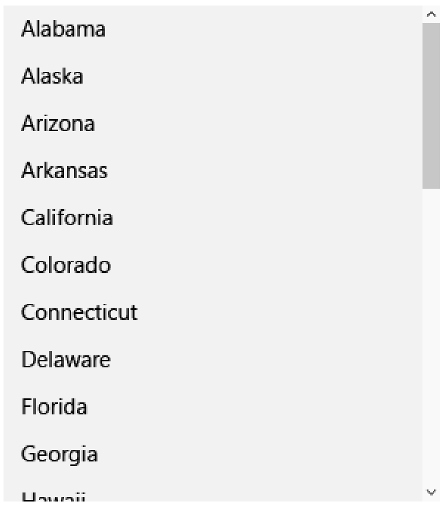
	
N/A	Web View 

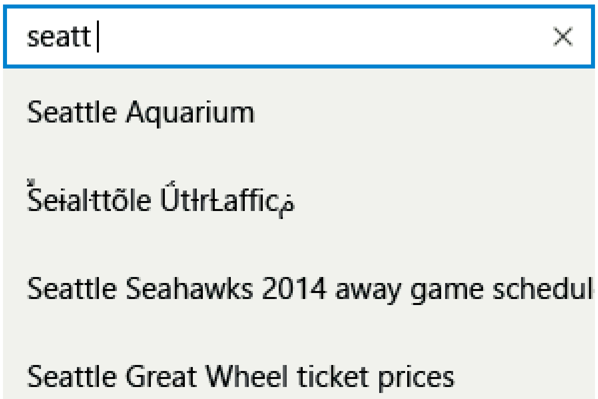
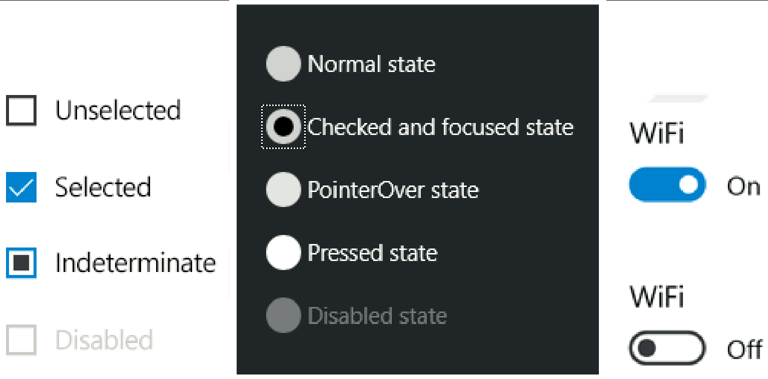
5.2.3. Command Elements / Controls

5.2.3.1. Command Elements of Microsoft

Command Elements of Microsoft are function elements which help users to utilize the applications by interacting. Command elements initiate actions, such as manipulating, saving, or sharing content. A list of command elements can be found below in Table 8:

Table 8: Command Elements of Microsoft

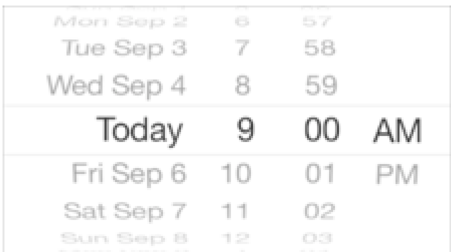
<table>
<tr><td>Buttons</td><td>
</td></tr>
<tr><td>Date and Time Pickers</td><td>
</td></tr>
<tr><td>Lists</td><td>
</td></tr>
</table>

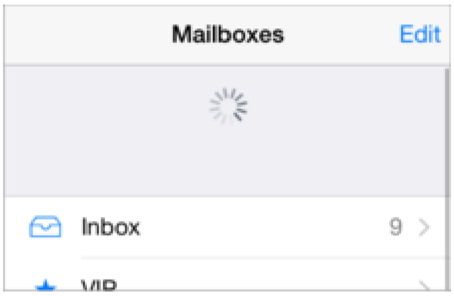
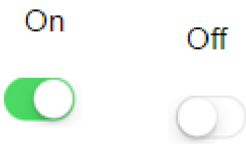
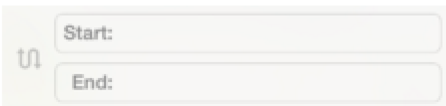
Predictive Text Entry	
Selection Control	

5.2.3.2. Controls of Apple

Apple design guideline consists of Controls. Controls are UI elements that enable users to interact with the system and give commands to the system. A list of command elements can be found below in Table 9:

Table 9: Controls of Apple

Button	
Picker	

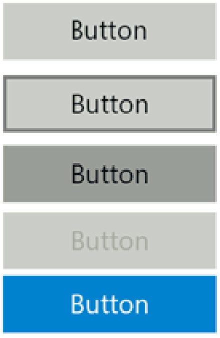
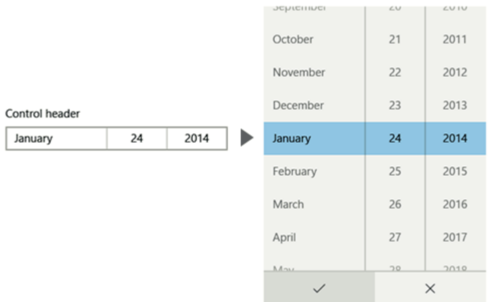
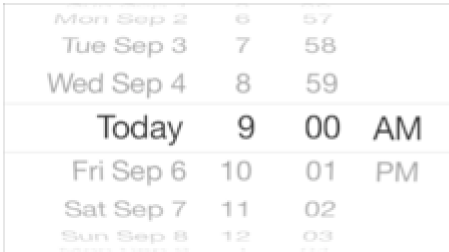
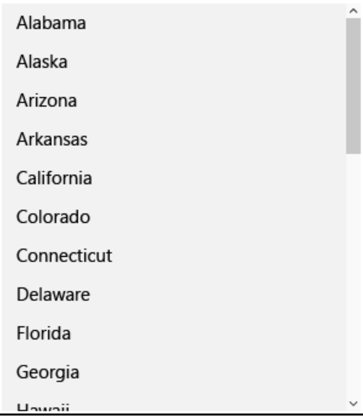
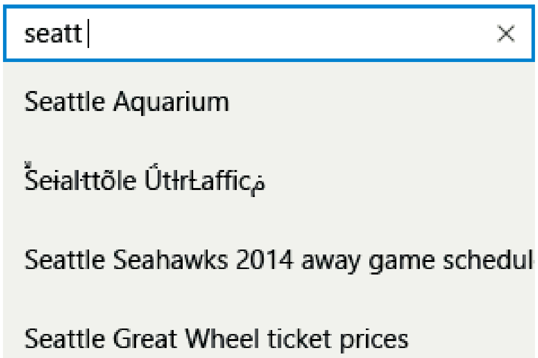
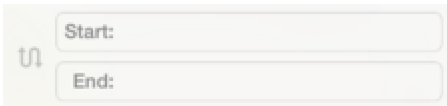
Label	
Refresh Control	
Segmented Control	
Slider	
Stepper	
Switch	
Text Field	

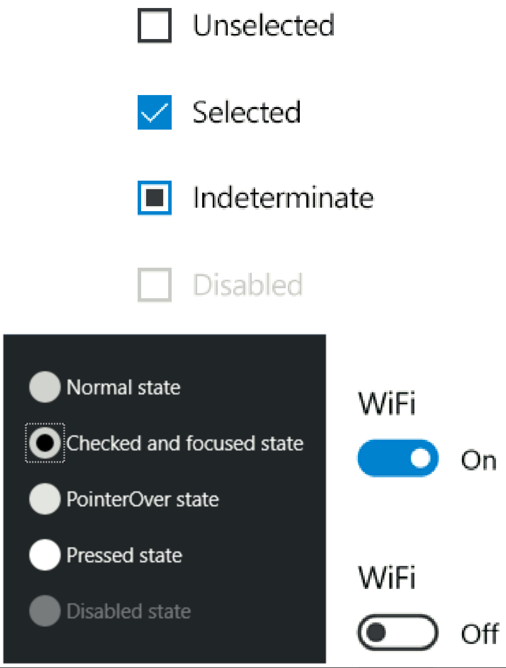
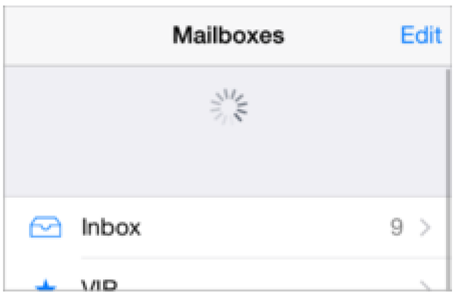
5.2.3.3. Differences and Similarities of Command Elements / Controls

Command Elements (Microsoft) / Controls (Apple) are function elements which help users to interact with an application. They enable users to interact with the system and give commands to the system. These elements enable users with a connection to a system to interact with the system. The most used command elements of Microsoft are buttons, date and time pickers, lists, predictive text entry, selection control where some of them are grouped together. Similarly, the most used control elements of Apple are, button, picker, label, refresh control, segmented control, slider, stepper, switch, text field. Buttons are possibly the most used interaction elements among them. They exist in both companies’ guidelines. We also directly use their guidelines and principles. However, when collaborative usage is taken into account, buttons should be designed accordingly. They should be large enough for a finger to fit on and be located carefully on the large-size screen to enable the desired user to interact easily. Another popular UI element on both platforms is pickers that gained importance with the emergence of touchscreens. This interaction element is easily usable for touch interaction. We also recommend the usage of pickers on large-size screens. The guidelines and principles dedicated to this UI element are also applicable for large-size screens. Besides, new suggestions such as larger interaction area and sub menu area can be used on large-size screen systems since the usable area is larger. The only drawback of pickers is that they are not suitable for collaborative usage. Only a single user can give a command with this UI element at a time. On the other hand, lists are also usable with touchscreen principles and multiple selection options are more suitable for collaborative usage. Similarly, the guidelines for lists can be easily adapted for large-size screen systems and some modifications about locating on the screen, size of the UI elements and collaborative usage ability can be added to these guidelines. Scroll elements are widely used on desktop-size systems however they are not fully adapted for touch interaction. Instead of using scroll elements, we recommend the use of slider, stepper and switch style UI elements favored by Apple. These are more suitable for touchscreen interaction and can easily be used on large-size screen systems. However collaborative usage of these items should be carefully taken into account and new designs can be created if necessary. Another very important interaction element is text entry. There are variations such as textbox, textfield, etc. but they are generally used to enter text to the system. This type of interaction element is necessary on mobile-size and desktop-size screens however large-size screens are primarily designed for providing data instead of receiving data. Thus text entry elements are not widely used on such systems. Still there is a need for this type of interaction. Thus guidelines created for desktop-size and mobile-size systems can be used for large-size systems. However soft keyboard usage should be considered and designs should include collaborative usage. Furthermore, visibility of these items and size of fonts matter since users of large-size screens can be situated away from the UI element. Location of the UI element shall also be considered. Other interaction elements can directly be used on large-size screen systems with their original guidelines and principles. No extra effort is necessary for these items. A side-by-side comparison of Microsoft and Apple UI elements can be seen in Table 10.

Table 10: Side-by-Side Comparison of Interaction Elements

Microsoft	**Apple**
Buttons	Button 

	
Date and Time Pickers 	Picker 
Lists 	Label 
Predictive text entry 	Text Field 
Selection Control	Segmented Control, Stepper, Switch 

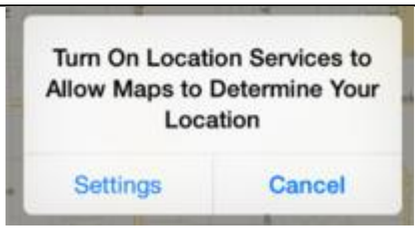
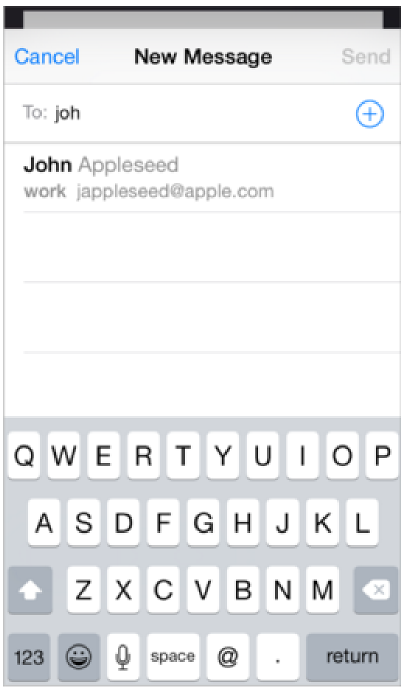
<table>
<tr><td></td><td></td></tr>
<tr><td>N/A</td><td>Refresh Control
</td></tr>
<tr><td>N/A</td><td>Slider
</td></tr>
</table>

5.2.4. Temporary Views

5.2.4.1. Temporary Views of Apple

Apple design guidelines also include Temporary Views which are used to give necessary feedback to the user and gather easy input from them. These UI elements are generally small and target oriented. A list of Temporary View elements can be found below in Table 11:

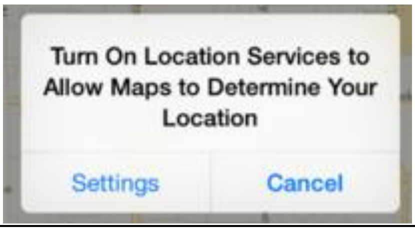
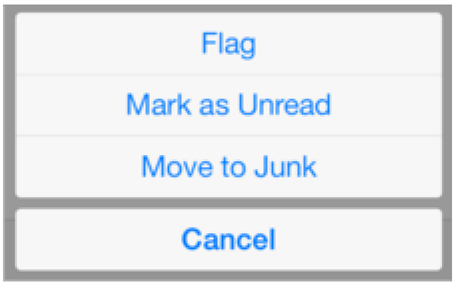
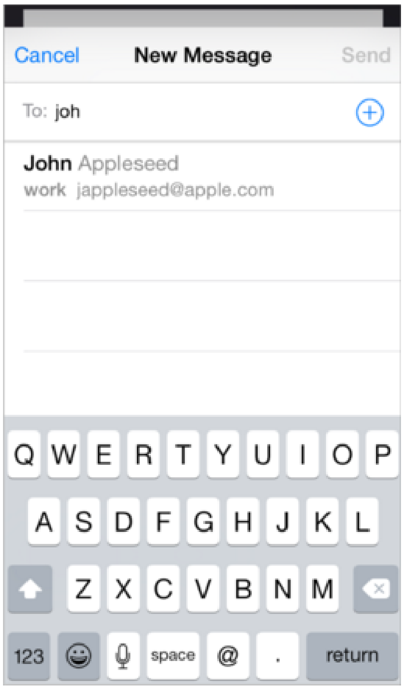
Table 11: Temporary Views of Apple

Alert	
Action Sheet	
Modal View	

5.2.4.2. Differences and Similarities of Temporary Views

There is no exact counterpart in the Windows design guidelines for Temporary Views used by Apple. However most of the items are covered in other parts of the UI element classification. This type is used to give necessary feedback to the user and gather easy input from the user. The UI elements in this part are alert, action sheet and modal view. A side-by-side comparison of Microsoft and Apple UI elements can be seen in Table 12.

Table 12: Side-by-Side Comparison of Feedback Elements

Microsoft	Apple
N/A	Alert 
N/A	Action Sheet 
N/A	Modal View 

CHAPTER 6

TESTS, RESULTS AND EVALUATION

In this chapter, we describe the tests that we have applied to evaluate large-size screen systems. According to the differences and similarities of large-size screen systems, existing HCI design guidelines and our observations from initial user experiences, we have created four laboratory and on site test scenarios. These tests cover nearly all of the open issues that exist. The following sections describe these test scenarios and surveys. In order to improve understanding, the results and evaluation of each test scenario is provided after the detailed description of the relevant test scenario.

6.1. Methodology of Statistical Analysis

In order to reveal statistical significance and gather meaningful results, the following statistical analyses were performed. Compliance with the normal distribution of continuous variables was checked using the Kolmogorov–Smirnov Test. Since, parametric test assumptions were available, comparisons were performed with the Paired Sample t-Test. Additionally, the Wilcoxon Signed Ranks test was used for comparisons between two dependent groups. The results of nonparametric tests were expressed as number of observations; mean ± standard deviation($\bar{\square} \pm \square$), median and minimum-maximum values [M(min-max)]. The Spearman's rank correlation coefficient was employed to evaluate the correlations between non-normally distributed variables. Data analyses were performed using the SPSS 17.0 Statistical Software (SPSS Inc., Chicago, IL, USA). A p value <0.05 was considered statistically significant.

6.2. Power Analysis

The sample size was chosen based on the study feasibility. Power analysis demonstrated that the sample size was adequate to achieve a greater than 80% power for all statistical tests. The power analyses were performed using the G*Power 3.1.9.2 Software (Franz Faul, Universitat Kiel, Germany).

6.3. Participants

A total of 30 people (21 (70%) males and 9 (30%) females) participated in this study. Their ages ranged between 19 and 33 with a mean age of 25.13 ± 3.84. A total of 76.7% of the participants had completed 4-year university education, and of the remainder 23.3% had completed higher education. 76.7% of the participants were IT related, 10% art related and 13.3% had occupations in other fields. Although no participants had large screen experience in the past, they described themselves as 70% 0-5 years experienced, 16.7% 5-10 years experienced and 13.3% higher experienced in HCI and usability.

6.4. Data Collection

Data was collected by several different methods during tests. First of all, we collected the click locations of users for each test with mouse interaction. Click times and intervals were also collected. Additionally, we collected touch locations and times for touch interaction. We displayed different shapes and asked the users to click or touch on them. We saved creation locations. We collected the number of click/touch errors. We also collected click/touch difference to the center of the shape for accuracy. We recorded video of the users with two different cameras while they were using the system. From the video records, we identified which user clicked on which shape. We also recorded manipulation details of shapes in terms of size, rotation and position. For the final test, we collected desired locations of each type of UI element. Once the tests were completed, we asked users some questions related to the tests and saved their answers. Collaboration and other similar issues were addressed by using the video records and by seeking to answer the following questions.

6.5. Test 1 – Direct vs. Indirect Control Pointing Devices on Large-Size Screen Systems

6.5.1. Hypotheses

Direct interaction methods such as touchscreen are faster than indirect interaction methods such as mouse on large-size screen systems.

Direct interaction methods are less error prone than indirect interaction methods on large-size screen systems.

Direct interaction methods create a higher immersion than indirect interaction methods on large-size screen systems.

Direct interaction methods are easier to learn on short term without major training than indirect interaction methods on large-size screen systems.

Direct interaction methods require less effort and create less tiredness than indirect interaction methods on large-size screen systems.

6.5.2. Purpose

Mouse and indirect control pointing is widely accepted on desktop-size devices. Touchscreen interaction is being used on mobile-size devices. They have both advantages and disadvantages. To determine which method is more suitable for large screen size systems, we created this test scenario.

6.5.3. Scenario

A program written by the author creates circles with a sequence on pre-defined locations on the screen, as shown in Figure 11. Each time only one circle occurs. The user is not aware where the circles will occur. For training purposes, the program first creates 5 circles and the user is asked to click on them with mouse. The program then creates 5 more circles and the user is requested to touch them with a finger. This initial part is not included in the analysis and is intended to help the user get used to the test. For the real test, there are two rounds. The user is shown 20-30 circles of 2-3 sets in the first round and 20-30 more circles of 2-3 sets at the horizontally flipped locations (to reduce left-right bias) in the second round. Before starting, the user is first asked to choose the interaction between mouse and touch. During the test, the shown item positions and clicked/touched positions as well as the creation times of items and click/touch times are recorded.

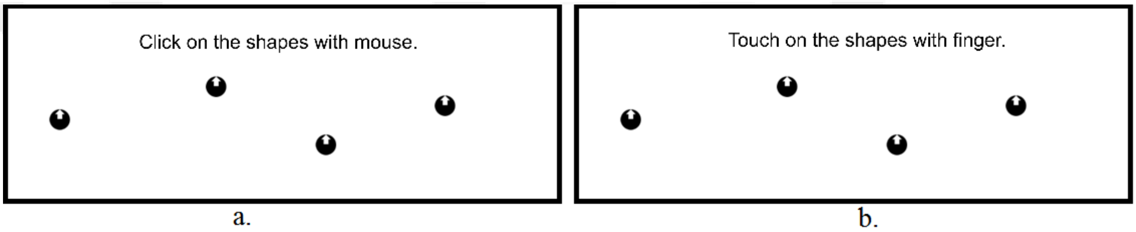


Figure 11: Test 1 Screen. a. First user is requested to click with mouse. b. User is requested to touch with finger.

6.5.4. Aims

- Which method is faster on large-size screen systems?
- Which method is less error prone on large-size screen systems?
- Which method creates a higher immersion on large-size screen systems?
- Which method is easier to learn on short term without major training?
- Which method requires less effort and creates less tiredness?

We tried to validate the “Direct-control pointing devices should be used” and “Direct manipulation should be adapted” guidelines with Test 1.

6.5.5. Results

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, neither of the values of Mouse Shown – Clicked Difference (MSCDiff), Touch Shown – Clicked Difference (TSCDiff), Mouse Hit Time (MHT) and Touch Hit Time (THT) fitted to normal distribution ($p<0.05$). Table for Kolmogorov-Smirnov Test is provided in APPENDIX F.

We received 1620 results with 30 participants and 54 shape positions. MSCDiff and TSCDiff in pixels are measured 45.78 ± 21.59 and 35.33 ± 17.17 respectively. 95%

confidence interval of the difference is (9.12, 11.77). According to the results, to compare the parameters of MSCDiff and TSCDiff, we applied nonparametric Wilcoxon Signed Ranks Test and found statistical significance ($p<0.05$). Table for Wilcoxon Signed Ranks Test is provided in APPENDIX F.

MHT and THT in milliseconds are measured with a mean of 1085 ± 238 and 1833 ± 705 respectively. We have received 1620 results with 30 participants and 54 shape positions. According to the results, to compare the parameters of MHT and THT we applied nonparametric Wilcoxon Signed Ranks Test and found statistical significance ($p<0.05$). Table for Wilcoxon Signed Ranks Test is provided in APPENDIX F.

We finally compared Mouse Error Count (MEC) and Touch Error Count (TEC). For MEC, 0 error count was 95.4%, 1 error count was 4.3%, 2 error count was 0.2% and 3 error count was 0.1%. For TEC, 0 error count was 95.5%, 1 error count was 4.4% and 2 error count was 0.1%. Chi-square Test revealed that the percentage of the error counts between MEC significantly differed with regard to TEC ($p < 0.05$). Table for Chi-square Test is provided in APPENDIX F.

6.6. Test 2 – Single User vs. Multiple User without Collaborative Task on Large-Size Screen Systems

6.6.1. Hypotheses

Large-size screen systems provide sufficient technological support for multiple user interaction so it is possible for several users to share the same large screen naturally.

Users can learn how to share the screen themselves.

Completing the same tasks with multiple users is more advantageous in terms of speed.

Single user environment is more error prone than multi-user environment.

6.6.2. Purpose

Large-size screen systems are considered to be used by several users simultaneously. When multiple users are to be accommodated, communication and collaboration have to be taken into account. To determine whether touchscreen direct-control pointing interaction and large display sizes are usable by several people, we created this test scenario.

6.6.3. Scenario

Program creates circles with a sequence on pre-defined locations on the screen. Each time only one circle occurs. The users are not aware where the circles will occur. Figure 12 shows an example snapshot of the participants during this test. For training, initially, the program creates 5 circles and multiple users are asked to touch on them. This initial part is not included in the analysis and is intended to help the users get used to the test. For the real test, 20-30 circles of 2-3 sets on pre-defined locations are shown to five simultaneous users. Users are not told which circles to click on and they are expected to decide themselves. During the test, the shown item positions and clicked/touched positions as well as the creation times of items and click/touch times are recorded. Figure 12 shows the actual test users who are using the system collaboratively at the same time.

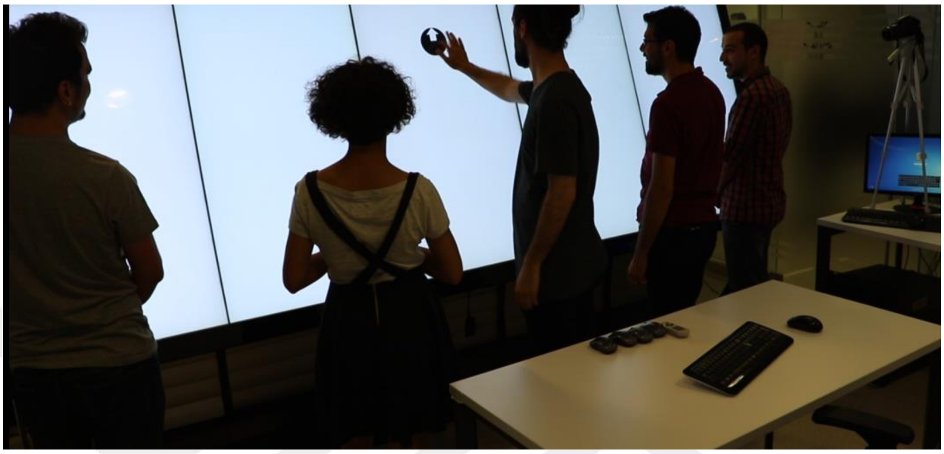


Figure 12: Test 2 Users testing collaboratively. Five users can use the system simultaneously. They communicate while completing the collaborative tasks.

6.6.4. Aims

- Do large-size screen systems provide enough technological support for multiple user interaction?
- Is it possible for several users to share the same large screen naturally?
- Can users learn how to share the screen themselves?
- Is completing the same tasks with multiple users more advantageous in terms of speed?
- Is single user environment or multi-user environment more error prone?

We tried to validate the "Touchscreen is the best, multi-touch is necessary" and "Collaborative usage should be considered" guidelines with Test 2.

6.6.5. Results

6.6.5.1. All Individual Participants vs. All Groups:

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of Group Touch Shown – Clicked Difference (GTSCDiff) fitted the normal distribution ($p>0.05$) whereas Group Touch Hit Time (GTHT) and Group Touch Error Count (GTEC) did not fit to normal distribution ($p<0.05$). Table for Kolmogorov-Smirnov Test is provided in

APPENDIX G. Thus we applied nonparametric Wilcoxon Signed Ranks Test and found statistical significance ($p<0.05$). Since participants in the groups were correlated to the participants in the individual experiments, we have used paired sample tests.

According to the results, Individual Mouse Shown – Clicked Difference (IMSCDiff) significantly differed from GTSCDiff ($p<0.05$). Mean of IMSCDiff is higher than the mean of GTSCDiff with values 45.78 ± 21.60 and 39.86 ± 19.24, respectively. Table for Wilcoxon Signed Ranks Test is provided in APPENDIX G.

Similarly, Individual Touch Shown – Clicked Difference (ITSCDiff) significantly differed from GTSCDiff ($p<0.05$). Mean of ITSCDiff is lower than the mean of GTSCDiff with values 35.33 ± 17.17 and 39.86 ± 19.24, respectively. Table for Wilcoxon Signed Ranks Test is provided in APPENDIX G.

Again, Individual Mouse Hit Time (IMHT) significantly differed from Group Touch Hit Time (GTHT) ($p<0.05$). Mean of IMHT is lower than the mean of GTHT with values 1085 ± 238 and 1297 ± 511, respectively. Table for Wilcoxon Signed Ranks Test is provided in APPENDIX G.

Similarly, Individual Touch Hit Time (ITHT) significantly differed from GTHT ($p<0.05$). Mean of ITHT is higher than the mean of GTHT with values 1833 ± 705 and 1297 ± 511, respectively. Table for Wilcoxon Signed Ranks Test is provided in APPENDIX G.

6.6.5.2. All Individual Participants vs. Their Own Groups:

Shape Location – Click Location Differences:

Comparisons of all differences are given in tabular form in APPENDIX H.

Group 1

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of TSCDiff and MSCDiff (both individuals and Group 1) fitted the normal distribution ($p>0.05$). Thus we applied parametric Paired Sample t-Test and a p value <0.05 was considered statistically significant. Since participants in the groups were correlated to the participants in the individual experiments, we have used paired sample tests.

Group 2

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of TSCDiff and MSCDiff (both individuals and Group 2) fitted the normal distribution ($p>0.05$). Thus we applied parametric Paired Sample t-Test and a p value <0.05 was considered statistically significant. Since participants in the groups were correlated to the participants in the individual experiments, we have used paired sample tests.

Group 3

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of TSCDiff and MSCDiff (both individuals and Group 3) fitted the normal distribution ($p>0.05$). Thus we applied parametric Paired Sample t-Test and a p value <0.05 was considered statistically significant. Since participants in the groups were correlated to the participants in the individual experiments, we have used paired sample tests.

Group 4

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of TSCDiff and MSCDiff (both individuals and Group 4) fitted the normal distribution ($p>0.05$). Thus we applied parametric Paired Sample t-Test and a p value <0.05 was considered statistically significant. Since participants in the groups were correlated to the participants in the individual experiments, we have used paired sample tests.

Group 5

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of TSCDiff and MSCDiff (both individuals and Group 5) fitted the normal distribution ($p>0.05$). Thus we applied parametric Paired Sample t-Test and a p value <0.05 was considered statistically significant. Since participants in the groups were correlated to the participants in the individual experiments, we have used paired sample tests.

Group 6

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of TSCDiff and MSCDiff (both individuals and Group 6) fitted the normal distribution ($p>0.05$). Thus we applied parametric Paired Sample t-Test and a p value <0.05 was considered statistically significant. Since participants in the groups were correlated to the participants in the individual experiments, we have used paired sample tests.

Hit Time Differences:

Comparisons of all differences are given in tabular form in APPENDIX H.

Group 1

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of THT (both individuals and Group 1) fitted the normal distribution ($p>0.05$). Thus we applied parametric Paired Sample t-Test and a p value <0.05 was considered statistically significant. Since participants in the groups were correlated to the participants in the individual experiments, we have used paired sample tests.

Group 2

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of Group2 THT did not fit the normal distribution ($p<0.05$). Thus we applied nonparametric Wilcoxon Signed Ranks Test and a p value <0.05 was considered statistically significant. Since participants in the groups were correlated to the participants in the individual experiments, we have used dependent tests.

Group 3

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of Group3 THT did not fit the normal distribution ($p<0.05$). Thus we applied nonparametric Wilcoxon Signed Ranks Test and a p value <0.05 was considered statistically significant. Since participants in the groups were correlated to the participants in the individual experiments, we have used dependent tests.

Group 4

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of Group4 THT did not fit the normal distribution ($p<0.05$). Thus we applied nonparametric Wilcoxon Signed Ranks Test and a p value <0.05 was considered statistically significant. Since participants in the groups were correlated to the participants in the individual experiments, we have used dependent tests.

Group 5

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of Group5 THT and all individual T (Hit Time) fitted the normal distribution ($p<0.05$). 1, 3, 4 M (Hit Time) fitted normal distribution. Thus we applied Paired Sample t-Test to the fitting values and we applied nonparametric Wilcoxon Signed Ranks Test to non-fitting values. A p value <0.05 was considered statistically significant. Since participants in the groups were correlated to the participants in the individual experiments, we have used dependent tests.

Group 6

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of Group6 THT did not fit the normal distribution ($p<0.05$). Thus we applied nonparametric Wilcoxon Signed Ranks Test and a p value <0.05 was considered statistically significant. Since participants in the groups were correlated to the participants in the individual experiments, we have used dependent tests.

Error Count Differences

Categorical variables were presented as percentage and were compared using the Pearson Chi-Square Test or Fisher’s Exact Test. A p value <0.05 was considered statistically significant. Comparisons of all differences are given in tabular form in APPENDIX H.

6.7. Test 3 – Collaborative Usage Effectiveness on Large-Size Screen Systems

6.7.1. Hypotheses

Using collaborative UI elements is faster than using standard UI elements.

Specifically designed tasks for collaborative usage provide better results in terms of speed, error and user immersion compared to non-collaborative usage.

There are practical problems of collaborative usage in terms of users.

Every part of the large-size screen can be seen while using the system collaboratively.

Collaborative usage is less error prone compared to non-collaborative usage.

6.7.2. Purpose

Using the same screen may not bring the whole potential of large-size screen interaction. Collaborative usage among the users is expected by the users to increase the speed and easiness and thus facilitate the interaction. To achieve this goal, we have created this test scenario to test whether the collaborative usage on collaborative UI elements are better for collaborative interaction on large-size screen systems.

6.7.3. Scenario

Random shapes consisted of triangle, rectangle and circle occurs on the left part of the large screen one at a time. At the same time, a slot with the same shape but different size occurs at the right part of the large screen. Users are expected to move, rotate and resize these shapes to match with the counterpart. Three users are asked to complete the task for 10 times. To complete the task, two different interaction methods are provided to the users. These interaction methods reflect collaborative and non-collaborative HCI. Two rounds are completed with two different interaction methods. The first round includes a UI element where the users can choose from moving, rotating and scaling modes. At each mode, users are able to complete the micro task with an indirect style UI element. At the second round, users are able to control the shapes using direct manipulation with their fingers. All the users are able to complete the micro tasks simultaneously and collaboratively. Prior to the study, a warm up session is given to the users to enable them get used to the test. During the test, the shown item positions and their creation times, clicked/touched positions, UI element preference, each operation in terms of move, rotate and zoom performed by each user, as well as the last states of each element and hit counts are recorded. Figure 13 shows the test screen of this test.

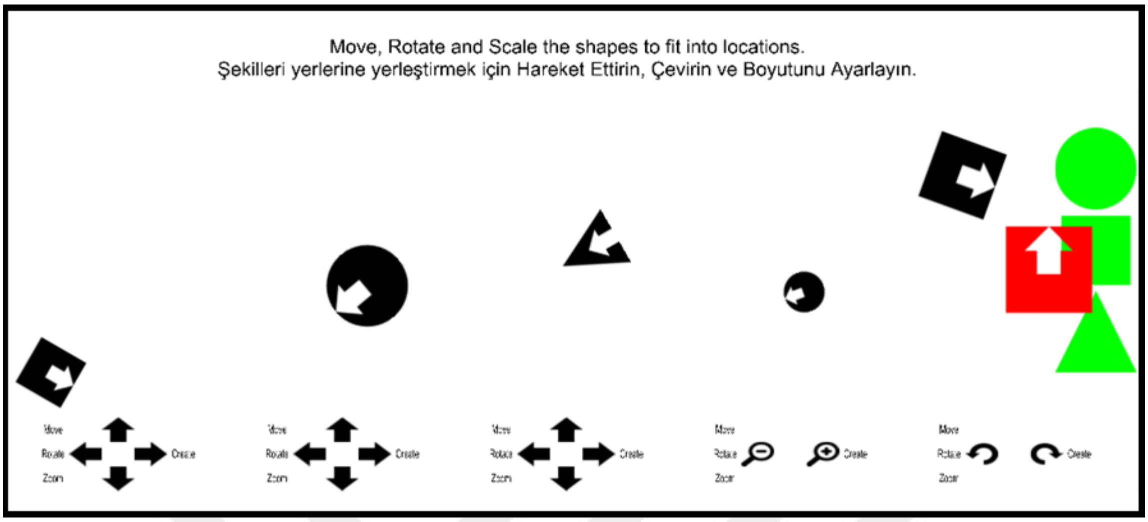


Figure 13: Test 3 Screen. Users Move, Rotate and Scale the items to fit into the corresponding goals.

6.7.4. Aims

- Are using collaborative UI elements faster than standard UI elements?
- Can specifically designed tasks for collaborative usage provide better results in terms of speed, error and user immersion?
- What are the practical problems of collaborative usage in terms of users?
- Can every part of the large-size screen be seen while using the system collaboratively?
- Is collaborative usage more error prone?

We tried to validate the "Enough surface for each user to see the content", "User collaboration phenomenon should be understood", "Collaborative tasks should be identified" and "UI Elements should be compatible with touch interaction principles" guidelines with Test 3.

6.7.5. Results

6.7.5.1. Differences According to Menu – Direct Manipulation

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the values of Menu Move (MM), Menu Rotate (MR) and Menu Zoom (MZ) did not fit the normal distribution ($p<0.05$). Table for Kolmogorov-Smirnov Test is provided in APPENDIX I. Thus we applied nonparametric Wilcoxon Signed Ranks Test and a p value <0.05 was considered statistically significant. Since participants in the tests were the same participants, we have used dependent test.

Table 13: Individual - Menu vs. Direct Manipulation. Single user menu usage vs. direct manipulation usage for move, rotate and zoom functions.

	Menu ($\bar{X}$±S) [M(min-max)] n=30	Direct ($\bar{X}$±S) [M(min-max)] n=30	p
MMIN - DMIN	0.67 ± 1.32 0(0-6)	12.6 ± 7.55 10.5(1-35)	<0.05*
MRIN - DRIN	0.90 ± 1.47 0(0-7)	10.47 ± 4.44 10(0-23)	<0.05*
MZIN - DZIN	1.27 ± 0.91 1(0-5)	8.47 ± 5.16 7(0-18)	<0.05*

Table 14: Group - Menu vs. Direct Manipulation. Group user menu usage vs. direct manipulation usage for move, rotate and zoom functions.

	Menu ($\bar{X}$±S) [M(min-max)] n=30	Direct ($\bar{X}$±S) [M(min-max)] n=30	p
MMGR – DMGR	0.67 ± 1.32 0(0-6)	99.00 ± 36.77 84.5(82-174)	<0.05*
MRGR – DRGR	1.67 ± 1.51 2(0-3)	49.50 ± 7.66 48.5(42-62)	<0.05*
MZGR - DZGR	4.00 ± 1.10 4(3-6)	29.67 ± 15.68 23(19-60)	<0.05*

Table 15: Individual vs. Group - Menu. Single user vs. group user with menu usage for move, rotate and zoom functions.

	Individual ($\bar{X}$±S) [M(min-max)] n=30	Group ($\bar{X}$±S) [M(min-max)] n=30	p
MMIN – MMGR	0.67 ± 1.32 0(0-6)	0.17 ± 0.41 0(0-1)	0.317
MRIN – MRGR	0.90 ± 1.47 0(0-7)	1.67 ± 1.51 2(0-3)	0.194
MZIN - MZGR	1.27 ± 0.91 1(0-5)	4.00 ± 1.10 4(3-6)	<0.05*

Table 16: Individual vs. Group – Direct Manipulation. Single user vs. group user with direct manipulation usage for move, rotate and zoom functions.

	Individual ($\bar{X}$±S) [M(min-max)] n=30	Group Gr ($\bar{X}$±S) [M(min-max)] n=30	p
DMIN – DMGR	12.6 ± 7.55 10.5(1-35)	99.00 ± 36.77 84.5(82-174)	<0.05*
DRIN – DRGR	10.47 ± 4.44 10(0-23)	49.50 ± 7.66 48.5(42-62)	<0.05*
DZIN - DZGR	8.47 ± 5.16 7(0-18)	29.67 ± 15.68 23(19-60)	<0.05*

Table 17: Individual vs. Group for Total Hit. Total number of successfully completed tasks for single user vs. group user.

	Individual ($\bar{X}$±S) [M(min-max)] n=30	Group ($\bar{X}$±S) [M(min-max)] n=30	p
THIN - THGR	7.40 ± 2.49 7(4-14)	26.17 ± 4.36 25.5(21-34)	<0.05*

6.7.5.2. Differences According to Each Action

We have used the Kolmogorov-Smirnov Test to check whether the sample data fits to normal distribution. According to this, the degrees of individual and group rotations and scales of individual and group zooms fit the normal distribution ($p>0.05$). Thus we applied parametric Independent Samples t-Test and a p value <0.05 was considered statistically significant. Homogeneity of Variance is also checked with Levene's Test.

According to the results, degree used with menu did not significantly differ by degree used with direct manipulation ($p>0.05$). Descriptive statistics are given in APPENDIX I.

While using the system collaboratively, none of the users manipulated rotations with menu interaction thus statistical comparison cannot be applied to the values. Descriptive statistics are given in APPENDIX I.

According to the results, scale used with menu significantly differed by scale used with direct manipulation ($p<0.05$) for individual usage. Descriptive statistics are given in APPENDIX I.

According to the results, scale used with menu significantly differed by scale used with direct manipulation ($p<0.05$) for group usage. Descriptive statistics are given in APPENDIX I.

6.8. Test 4 – UI Element Location and Size on Large-Size Screen Systems

6.8.1. Hypotheses

Locations of visual, interaction and feedback UI elements differ according to standard and small size screen systems.

Locations near to the users on large-size screens are much more convenient for interaction with UI elements compared to locations farther away from them.

Collaboration centric UI elements make difference in terms of usability.

6.8.2. Purpose

UI elements are one of the major parts of human-computer interaction. Main interaction is completed via these UI elements. According to this, each system requires dedicated UI elements for special needs and usage. Therefore, we tested UI elements especially for large-size screen systems. UI elements are classified as Visual UI Elements, Interaction UI Elements and Feedback UI Elements. These groupings are made according to the existing UI design guidelines and principles of well-known companies. Figure 14 shows the screen for this test.

Figure 14: Test 4 Screen. Visual UI element, interaction UI element, feedback UI element, background and decision panel are shown at the same time.

6.8.3. Scenario

Three different UI elements are shown to the users in this test. Each of the UI elements refers to a different type in UI element groups given in purpose above. A background is also shown to the users to mimic real applications. Each user is asked to choose the most appropriate position on the screen for each different UI element. Users were able to choose the position and size from a menu at the left of the screen. Users were then asked to decide the locations for collaborative usage of large-size screen systems.

6.8.4. Aims

- Which locations on large screens are better for visual, interaction and feedback UI elements?
- How much area is necessary for each UI element on the screen?
- Which locations on large screens are better for interaction with UI elements?
- Do collaboration centric UI elements make any difference in terms of usability?

We tried to validate the “Define main visible areas”, “Define main interaction areas”, “Understand UI Element locations”, “Feedback should be visual and visible to all users”, “Feedback location should be considered” and “New UI Elements should be designed for large screens and collaborative use” guidelines with Test 4.

6.8.5. Results

Frequency tables are given for locations of visual, interaction and feedback UI elements according to the decisions of 30 participants.

Table 18: Visual UI Elements.

Location	Frequency	Percentage (%)
Aligned	15	50.0%
Attached	5	16.7%
Free	10	33.3%

Table 19: Interaction UI Elements.

Location	Frequency	Percentage (%)
Aligned	10	33.3%
Attached	10	33.3%
Free	10	33.3%

Table 20: Feedback UI Elements.

Location	Frequency	Percentage (%)
Aligned	0	0.0%
Attached	0	0.0%
Free	30	100.0%

6.9. Questionnaires

Questionnaires were given to the users just after they have used the system and completed the tests. Their answers were collected and results are shown in terms of respective percentages. Below are the results for each questionnaire. Likert scale from 1 to 5 is applied to all the questionnaires.

To evaluate our system, we used survey methodology to test the final product on users. Accordingly, we prepared a background questionnaire, a questionnaire for user interface satisfaction (Chin, Diehl, & Norman, 1988), a perceived usefulness and ease of use questionnaire (Davis, 1989) and two usability questionnaires (Nielsen, 1994; Hart & Staveland, 1988). Background questionnaire contains the questions of age, gender, education level, profession and experience. User interface satisfaction questionnaire is based on the studies of Chin et al. (Chin, Diehl, & Norman, 1988). Acceptability questionnaire is based on the Technology Acceptance Model (TAM) of Davis et al. (Davis, 1989). Usability questionnaires are based on the studies of Nielsen (Nielsen, 1994) and NASA Task Load Index (Hart & Staveland, 1988). Questions for each questionnaire are provided in APPENDIX A, APPENDIX B, APPENDIX C, APPENDIX D and APPENDIX E.

Table 21: Results of Questionnaire for User Interface Satisfaction.

OVERALL REACTION TO THE SOFTWARE (Results are given in percentages (%))								
1.	Overall Reaction to the Software	terrible	0.0	0.0	43.3	50.0	6.7	wonderful
2.	Overall Reaction to the Software	difficult	0.0	6.7	13.3	46.7	33.3	easy
3.	Overall Reaction to the Software	frustrating	0.0	6.7	30.0	53.3	10.0	satisfying
4.	Overall Reaction to the Software	inadequate power	0.0	3.4	31.0	44.8	20.7	adequate power
5.	Overall Reaction to the Software	dull	0.0	7.1	25.0	50.0	17.9	stimulating
6.	Overall Reaction to the Software	rigid	0.0	6.9	31.0	55.2	6.9	flexible
SCREEN								
7.	Organization of information	confusing	0.0	0.0	13.3	33.3	53.3	very clear
8.	Sequence of screens	confusing	0.0	0.0	10.0	46.7	43.3	very clear
TERMINOLOGY AND SYSTEM INFORMATION								
9.	Use of terms throughout system	inconsistent	0.0	0.0	6.9	41.4	51.7	consistent
10.	Terminology related to task	never	3.3	3.3	13.3	43.3	36.7	always
11.	Position of messages on screen	inconsistent	0.0	3.3	23.3	30.0	43.3	consistent
12.	Prompts for input	confusing	0.0	3.3	13.3	40.0	43.3	clear
13.	Computer informs about its progress	never	10.0	6.7	16.7	36.7	30.0	always
14.	Error messages	unhelpful	6.9	6.9	48.3	24.1	13.8	helpful
LEARNING								
15.	Learning to operate the system	difficult	0.0	0.0	6.7	40.0	53.3	easy
16.	Exploring new features by trial and error	difficult	0.0	6.7	10.0	40.0	43.3	easy
17.	Remembering names and use of commands	difficult	0.0	3.3	20.0	26.7	50.0	easy
18.	Performing tasks is straightforward	never	0.0	0.0	10.0	53.3	36.7	always
19.	Help messages on the screen	unhelpful	0.0	6.7	43.3	23.3	26.7	helpful
SYSTEM CAPABILITIES								
20.	System speed	too slow	3.3	13.3	16.7	26.7	40.0	fast enough
21.	System reliability	unreliable	0.0	10.3	27.6	41.7	20.7	reliable
22.	System tends to be	noisy	0.0	6.7	13.3	30.0	50.0	quiet
23.	Correcting your mistakes	difficult	0.0	10.3	27.6	37.9	24.1	easy
24.	Designed for all levels of users	never	0.0	10.0	30.0	33.3	26.7	always

Table 22: Results of Questionnaire for Perceived Usefulness and Ease of Use.

PERCEIVED USEFULNESS (Results are given in percentages (%))						
1.	Using the system in my job would enable me to accomplish tasks more quickly	13.3	20.0	26.7	26.7	13.3
2.	Using the system would improve my job performance	13.3	20.0	26.7	33.3	6.7
3.	Using the system in my job would increase my productivity	10.0	20.0	30.0	33.3	6.7

4.	Using the system would enhance my effectiveness on the job	13.3	16.7	20.0	43.3	6.7
5.	Using the system would make it easier to do my job	16.7	23.3	20.0	33.3	6.7
6.	I would find the system useful in my job	10.0	30.0	20.0	36.7	3.3
PERCEIVED EASE OF USE						
7.	Learning to operate the system would be easy for me	3.3	3.3	3.3	30.0	60.0
8.	I would find it easy to get the system to do what I want it to do	0.0	6.7	23.3	33.3	36.7
9.	My interaction with the system would be clear and understandable	0.0	6.7	13.3	53.3	26.7
10.	I would find the system to be flexible to interact with	0.0	10.0	16.7	43.3	30.0
11.	It would be easy for me to become skillful at using the system	0.0	3.3	20.0	40.0	36.7
12.	I would find the system easy to use	0.0	3.3	23.3	33.3	40.0

Table 23: Results of Questionnaire for NASA Task Load Index.

NASA TASK LOAD INDEX (Results are given in percentages (%))						
1.	Mental Demand How mentally demanding was the task?	23.3	23.3	26.7	23.3	3.3
2.	Physical Demand How physically demanding was the task?	10.0	13.3	23.3	33.3	20.0
3.	Temporal Demand How hurried or rushed was the pace of the task?	13.3	10.0	40.0	36.7	0.0
4.	Performance How successful were you in accomplishing what you were asked to do?	16.7	43.3	30.0	6.7	3.3
5.	Effort How hard did you have to work to accomplish your level of performance?	13.3	20.0	40.0	23.3	3.3
6.	Frustration How insecure, discouraged, irritated, stressed, and annoyed were you?	46.7	33.3	16.7	3.3	0.0

Table 24: Results of Questionnaire for Nielsen's Attributes of Usability.

NIELSEN'S ATTRIBUTES OF USABILITY (Results are given in percentages (%))						
1.	Learnability	0.0	0.0	6.7	36.7	56.7
2.	Efficiency	0.0	10.0	20.0	50.0	20.0
3.	Memorability	0.0	0.0	13.3	46.7	40.0
4.	Errors (Accuracy)	6.7	23.3	33.3	20.0	16.7
5.	Subjective Satisfaction	0.0	3.4	24.1	48.3	24.1

CHAPTER 7

PROPOSED GUIDELINES AND PRINCIPLES

As a result of literature search, methodologic studies, initial experiences and observations, differences and similarities of large-size screen systems vs. desktop-size screen systems and mobile-size screen systems, existing guidelines and principles of well-known companies and laboratory experiments and statistical usability analysis; we have created our design guidelines and principles for creating the interaction design of large-size screen systems. This chapter describes these guidelines and principles in terms of human-computer interaction principles. Section 1 describes "Interaction Style & Data Entry" guidelines and principles. Section 2 describes "Display" guidelines and principles. Section 3 describes "User Skill Level" guidelines and principles. Section 4 describes "Task and Goal" guidelines and principles. Section 5 describes "Navigation thru Interface" guidelines and principles. Section 6 describes "Display Organization" guidelines and principles. Section 7 describes "UI Element" guidelines and principles. Section 8 describes "Feedback" guidelines and principles.

7.1. Interaction Style & Data Entry

7.1.1. Keyboard should not be a dedicated hardware, it should be on-screen.

7.1.1.1. Similarities

- On-screen keyboards are also widely used and they do not require any extra hardware. They are widely popular on mobile devices (Ref. Sec. 2.2.1).
- With the help of on-screen keyboards, mobile device users do not need to carry any extra hardware near them and assign the required space to display elements (Ref. Sec. 2.2.1).
- Third-party devices are not used (Ref. Sec. 4.1 – SIM5).
- On-screen keyboards are used (Ref. Sec. 4.1 – SIM6).
- Third-party devices are not used (Ref. Sec. 4.1 – SID2).

7.1.1.2. Differences

- Generally, these systems are used for mass data entry. Word processing applications are possibly the most used applications on desktop computers (Encyclopedia.com, 2015). This situation yields high use rate of the keyboard. However large-size screen systems are generally used for distribution of knowledge instead of collecting knowledge (Pekin, İşler, & Günel, 2015).

- A dedicated keyboard or similar device is not used with the system. Such devices require a physical location. A dedicated table or some kind of tray is necessary to operate these devices. Large-size screen systems typically have vertical displays and people stand close to them. Pointing is undertaken with the help of touchscreens thus users have to be close to the screen. When this is the situation there is insufficient space available for locating additional hardware between the user and the display (Ref. Sec. 2.2.1).

- Single on-screen keyboard is provided (Ref. Sec. 4.1 – DIM4).

- There is enough physical location to put a single mouse and keyboard (Ref. Sec. 4.1 – DID3).

7.1.1.3. Results

Mobile devices and similar touchscreen systems widely use on-screen keyboards. This method does not require any extra hardware and extra space to use. Third party devices are eliminated by using the on-screen keyboard and this yields better immersion. Taking these factors into account, large-size screens have a similar usability potential and thus, on-screen keyboard usage is advised on large-size screen systems. On the other hand, large-size screens have differences in terms of on-screen keyboard usage than other systems. Desktop-size systems are generally used for mass data entry and large-size screen systems are used for data retrieval. Large-size screen systems do not generally have a dedicated space for interaction devices whereas desktop-size systems have. One other difference is that mobile devices have only a single on-screen keyboard where large-size screens need more than that since they have multi simultaneous users.

As a conclusion, large-size screen systems are advised to have an on-screen keyboard and they do not require dedicated hardware for text input.

7.1.2. Auto complete is not necessary.

7.1.2.1. Similarities

- None

7.1.2.2. Differences

- …such systems are not generally built to enter textual data into the system. Instead they are meant to present data to the user. Need for textual input in serious games is limited. Only communication issues require some textual data in general. Thus the same guidelines and principles can be followed as mobile devices. Since dense data input is not required, there is no need for auto-complete type features. Besides some novel terminological and specific words can be used by the users of serious games and these words may not be included in any vocabulary. Since they are not present in any vocabulary, auto-complete features may not be used with high precision (Ref. Sec. 2.2.1).

- Auto complete is more appropriate for single users (Ref. Sec. 4.1 – DIM5).

7.1.2.3. Results

As suggested in the differences and similarities and the existing guidelines, there is no need for an auto complete function for text entry. Large-size screen systems are generally used for specific purposes and generally the vocabulary is dedicated to the purpose. Furthermore, entered text may not be a correct word every time. For example, a serious game for military education may contain a number of novel abbreviations which can be entered to the system.

In conclusion, large-size screen systems are not advised to feature auto complete functionality on text input.

7.1.3. Direct-control pointing devices should be used.

7.1.3.1. Similarities

- Touchscreens began to be a popular choice for applications where users are novice and keyboard are not required. Designers like to use them for public-access systems because they contain no moving parts and their durability is very high (Ref. Sec. 2.2.2.2).

- Touchscreens allow their users to directly touch arbitrary locations on screens and interact with the system. This approach was rapidly adopted for use on mobile devices and public kiosks. Touchscreens began to be favored for applications where users are novice and a keyboard is thought unnecessary (Ref. Sec. 2.2.2.2).

- Third-party devices are not used (Ref. Sec. 4.1 – SIM5).

7.1.3.2. Differences

- The mouse is one of the most used input devices because it is inexpensive and widely available. It also is comfortable to use since users can rest their arm on a desk while using it (Ref. Sec. 2.2.2.2).

- Users, who are located near the screen, have difficulties using a mouse pointer. Thus instead of using a mouse, touch screen interaction is preferred on large screens (Pekin, İşler, & Günel, 2015).

- Large screen systems aim to create enhanced virtual reality with high immersion using a large viewing area but third party interaction devices reduces this immersive effect which is not desired for such systems (Maarse, Mulder, Brand, & Akkerman, 2006).

- Cursor is easy to find on screen where only a single cursor is used (Ref. Sec. 4.1 – DID2).

- There is sufficeint physical space to locate a single mouse and keyboard (Ref. Sec. 4.1 – DID3).

7.1.3.3. Tests

With Test 1, this guideline is validated and can be used on large-size screen systems.

7.1.3.4. Results

Since touchscreens are popular on public access systems and their maintainability is high, large-size screen systems are suitable for touchscreen use. Touchscreen interaction can be used for various types of data entry such as text. In using touchscreens, third-party interaction devices become unnecessary. Accordingly, large-size screens are similar to mobile-size and desktop-size systems which use touchscreens. However, desktop-size systems which use a mouse have different properties than large-size screens. A mouse is the most used input device on desktop-size systems. Users of desktop devices are located away from the screen thus there is adequate space to operate the mouse. Desktop-size devices are not generally used to create extended immersion thus indirect control devices can be used. Similarly, the mouse cursor as the result of indirect control pointers is not a problem since there is only a single user at a time.

In conclusion, direct control pointing devices should be used on large-size screen systems instead of indirect control pointing devices.

7.1.4. Direct manipulation should be adapted.

7.1.4.1. Similarities

- Touchscreens allow their users to directly touch arbitrary locations on screens and interact with the system. This is a very robust method and was rapidly applied for use on mobile devices and public kiosks (Ref. Sec. 2.2.2.2).

- Direct manipulation interaction is a good choice for mobile devices (Gartner.com, 2015). The same interaction technique is used on both large screens and mobile-size screens.

- Both use touch interaction (Ref. Sec. 4.1 – SIM1).

- Direct manipulation is used to provide data (Ref. Sec. 4.1 – SIM2).

7.1.4.2. Differences

- It is easy to use a mouse because users use their forearm to move long distances and fingers to handle precise positioning (Ref. Sec. 2.2.2.2).

- Users need to practice to use indirect controlling precisely (Ref. Sec. 2.2.2.2).

- Users of large-sized systems are not using these devices for long periods thus they do not tire of using a direct manipulation technique on these systems which enhances the virtual reality feeling (Maarse, Mulder, Brand, & Akkerman, 2006).

7.1.4.3. Tests

With Test 1, this guideline is validated and can be used on large-size screen systems.

7.1.4.4. Results

Touchscreens enable their users to use direct a manipulation technique. Since large-size screen systems are intended to be used by several people, users need to feel comfortable while manipulating the content on the screen. Direct manipulation is a good approach where the objective is to for the manipulation of several different objects by several different users. Mobile devices benefit from the direct manipulation principle since it is faster and more robust than other interaction techniques. Desktop devices do not generally adopt this principle. They are often designed to include several other human-computer interaction styles such as command entry and function keys. In contrast to indirect controlling devices, using direct controlling pointing devices with direct manipulation can be tiring but since large-size screens are not used for long hours, this should not be a significant problem.

In conclusion, the direct manipulation technique is highly recommended on large-size screen devices where it is appropriate.

7.1.5. Touchscreen is the best, multi-touch is necessary.

7.1.5.1. Similarities

- Multiple-touch touchscreens are already popular and used on several devices. Such touchscreens allow their users to use both hands or more than one finger at once. It is also possible that multiple users can use multiple-touch touchscreens simultaneously on a shared surface (Ref. Sec. 2.2.2.4).

- Another already successful multi-touch implementation is the screens of mobile devices. Since the introduction of this technology by iPhone, gestural interaction and overall usage of mobile devices have increased significantly (Ref. Sec. 2.2.2.4).

- Both use touch interaction (Ref. Sec. 4.1 – SID1).

7.1.5.2. Differences

- Single handed touch is possible (Ref. Sec. 4.1 – DIM1).
- More than one user cannot hold and use simultaneously (Ref. Sec. 4.1 – DIM3).
- Multi-touch is not available (Ref. Sec. 4.1 – DID5).

7.1.5.3. Tests

With Test 2, this guideline is validated and can be used on large-size screen systems.

7.1.5.4. Results

Multi-touch touchscreens enable their users to use both hands simultaneously. They also enable several users to use them at the same time. Mobile devices are now capable to get multi-touch commands. This technique also enabled complex gestures to be used as input. There are also differences between mobile-size screens and large-size screens. Only a single hand can fit on the screen on mobile devices, they are also designed for handheld usage. Desktop-size devices do not generally accept multi-touch commands.

As a conclusion, multi-touch can be used on large-size screen devices to enable collaborative usage of large-size screens.

7.1.6. Audio and visual input is not mandatory for current purposes.

7.1.6.1. Similarities

- None

7.1.6.2. Differences

- Audio and visual inputs can be provided (Ref. Sec. 4.1 – DIM6).
- Audio and visual inputs can be provided (Ref. Sec. 4.1 – DID4).

7.1.6.3. Results

Mobile-size and desktop-size devices accept audio and visual inputs. Large-size screen systems do not generally accept these types of commands since there are several people using these devices simultaneously and it is difficult to understand who is giving the command.

In conclusion, audio and visual inputs may not be supported on large-size screen systems.

7.1.7. Gestural interaction should be considered.

7.1.7.1. Similarities

- Gestures are used (Ref. Sec. 4.1 – SIM4).

7.1.7.2. Differences

- One or two finger gestures are common (Ref. Sec. 4.1 – DIM2).

7.1.7.3. Results

Gestural interaction is generally designed for mobile-size devices and are not widely available on desktop-size devices. On the other hand, mainly one or two finger gestures are designed for gesture libraries. This may not be the case for large-size screens. Two handed gestures and collaborative gestures can also be built for large-size screen interaction.

In conclusion, gestural interaction should be supported on large-size screens. Gesture libraries can extend existing gesture libraries and they can be expanded with the addition of new type of gestures such as two handed and collaborative gestures.

7.1.8. Collaborative usage should be considered.

7.1.8.1. Similarities

- Capable of multi-touch (Ref. Sec. 4.1 – SIM3).
- There is enough usage area for several users to interact with the system (Ref. Sec. 4.1 – SID1).
- All users can easily see and interact data entry (Ref. Sec. 4.1 – SID3).
- More than one user can enter data at the same time (Ref. Sec. 4.1 – SID4).

7.1.8.2. Differences

- Single handed touch is possible (Ref. Sec. 4.1 – DIM1).
- More than one user cannot hold and use simultaneously (Ref. Sec. 4.1 – DIM3).
- Mouse, keyboard and other interaction devices are used-a dedicated device has to be assigned to each user (Ref. Sec. 4.1 – DID1).
- Multi-touch is not available (Ref. Sec. 4.1 – DID5).

7.1.8.3. Tests

With Test 2, this guideline is validated and can be used on large-size screen systems.

7.1.8.4. Results

Large-size screen systems are capable of multi-touch as in mobile-size systems. Multi-touch principles can be used for collaborative interaction. Desktop-size screen devices enable their users to see and interact with the content at the same time and this type of interaction can be studied to collect data for collaborative usage of large-size screen systems. However, there are differences between mobile-size screens and large-size screens in terms of collaborative usage. Mobile-size devices are designed for single handed interaction and single user. Desktop-size devices, on the other hand, use indirect controlling pointer devices which have to be assigned to each user. They do not provide the multi-touch capabilities which are better for collaborative usage.

In conclusion, collaborative usage should be adapted for large-size screens. New principles can be created by analyzing both mobile-size screen devices and desktop-size screen devices.

7.2. Display

7.2.1. Enough surface for each user to see the content.

7.2.1.1. Similarities

- SMART Board application of SMART Technologies, Inc. provides such a system for large interactive display systems. It uses the content from a general purpose desktop computer displayed on a large touchscreen display (Ref. Sec. 2.3.1.3).

- Multi-desktop displays are useful for specific applications. Modeling or coding is highly efficient on such environments. Video editing, content generation tasks and timeline related issues also require a large view nowadays. It is also useful if several windows are open at the same time (Ref. Sec. 2.3.1.3).

- Desktop-size screen devices have sufficient space on screen but a mouse and similar interaction devices are used and this causes smaller UI elements to be used.

- Each part of screen is in the field of view for multi-user (Ref. Sec. 4.1 – SDD1).

7.2.1.2. Differences

- There are current problems in the mobile environment where screens are still small, and it is difficult to see the content provided on the display (Ref. Sec. 2.3.1.1).

- Web pages designed for desktop display are not suitable for mobile devices. There are lots of images spread all over the page. High resolution areas are problematic on small screens. Website content needed to be adapted for use on mobile devices. New designs contain less menu interaction, optimized screen resolution and vertical scroll based navigation. Other approaches include summarizing text content, data suppression and using compact overviews (Ref. Sec. 2.3.1.1).

- Mobile devices are designed to let their users use them with one hand (Karlson & Bederson, 2007). These devices are physically small and the area on screen can therefore only contain a small number of elements.

- Every part of the screen is visible for all users (Ref. Sec. 4.1 – DDM1).

- Paging principle is applied since screen is too small (Ref. Sec. 4.1 – DDM4).

7.2.1.3. Tests

With Test 3, this guideline is validated and can be used on large-size screen systems.

7.2.1.4. Results

Several displays are combined together on multi display desktop systems. This enables several users to see the content at the same time. Users can collaborate on the same task since they have enough vision to see the whole content. Every part of the screen is visible to each user on desktop-size devices. On the other hand, mobile-size devices have difficulties when it comes to display area. The content does not fit in the screen most of the time. This yields the paging principle which is not used on large-size screens and this requires a user to change view to see the content. Additionally, since the screen is small, some users have difficulties seeing the content at the same time.

In conclusion, since collaboration has to be supported, enough surface area should be provided to each individual user to enable them see and manipulate the content simultaneously.

7.2.2. Head mounted displays and similar displays are not suitable for collaboration.

7.2.2.1. Similarities

- None

7.2.2.2. Differences

- Head-up display technology enable drivers to maintain their view of the road as much as possible (Ref. Sec. 2.3.1.2).

- According to the direction data of the user's head, the virtual image is recalculated and shown to the user creating the effect of virtual reality. The created image cannot be seen by any other user at this time (Ref. Sec. 2.3.1.2).

- Resolution is smaller relative to desktop displays, however significant progress has been received recently and the technology provides promise for the future. Possibly the most important disadvantage is that each user has to have one device to see the content (Ref. Sec. 2.3.1.2).

7.2.2.3. Results

Head-up displays, head-mounted displays and several other single person technologies are not suitable for large-size screen devices. Head-up display technology is generally used in vehicles to display information to the driver or pilot. Head-mounted displays are used to increase virtual reality but are only suitable for single users.

In conclusion, since these types of displays are suitable for single person usage, it is not advised to use them with large-size screen systems for collaborative interaction.

7.3. User Skill Level

7.3.1. User skill levels and user domains should be analyzed.

7.3.1.1. Similarities

- None

7.3.1.2. Differences

- Desktop-size screen device users are more experienced with the applications they are using or get used to those programs (Pekin, İşler, & Günel, 2015).

- Mobile-size screen device users are generally familiar with the general user interface principles because of their prior experience on similar applications (Pekin, İşler, & Günel, 2015).

- Users are not expert about the domain (Ref. Sec. 4.1 – DMU3).

- Users are not expert about the domain (Ref. Sec. 4.1 – DUD3).

7.3.1.3. Results

For desktop-size devices and mobile-size devices, user skill levels and domains are well-known. Applications and designs are created according to these principles. For large-size screen systems, this data is missing or different for each application. Thus designers should analyze user skill levels and domains prior to design.

In conclusion, user skill levels and user domains should be analyzed before creating such systems and designs should be made according to this data.

7.3.2. User practice and reuse should be considered.

7.3.2.1. Similarities

- Even though they do not have high level technical knowledge, they are experienced on similar devices and applications for content management.
- Users use an application for long periods (Ref. Sec. 4.1 – SUD2).

7.3.2.2. Differences

- Users have an opportunity to practice applications several times (Ref. Sec. 4.1 – DUM1).
- Users have experience on similar devices (Ref. Sec. 4.1 – DUM2).
- Users have opportunity to practice applications several times (Ref. Sec. 4.1 – DUD1).

7.3.2.3. Results

Mobile-size screen device users are using their system frequently which trains them in terms of usability. Similarly, desktop-size screen device users also use their devices frequently. Large-size screen systems are not build for regular everyday use thus their users do not gain experience by using them every day or for long periods.

In conclusion, since users are not familiar with the system and they do not have opportunity to practice frequently, user interaction should be designed accordingly. Users should not be required to remember or reveal features.

7.3.3. User collaboration phenomenon should be understood.

7.3.3.1. Similarities

- Users are not familiar with collaborative interfaces (Ref. Sec. 4.1 – SUM1).
- Users are not familiar with collaborative interfaces (Ref. Sec. 4.1 – SUD1).

7.3.3.2. Differences

- Users do not use the same device collaboratively (Ref. Sec. 4.1 – DMU4).
- Users do not use the same device collaboratively (Ref. Sec. 4.1 – DUD4).

7.3.3.3. Tests

With Test 3, this guideline is validated and can be used on large-size screen systems.

7.3.3.4. Results

Mobile-size screen users and desktop-size screen users do not use their systems collaboratively. On the other hand, users of large-size screen systems have to use the system collaboratively. They may not be familiar with the principle but they are required to use it.

In conclusion, since the users are expected to be unfamiliar with collaborative usage, they should be educated or given instruction before they use the system. Designs should be completed according to these principles and users shall be able to easily understand how to use the system collaboratively.

7.3.4. Learning curve should be estimated.

7.3.4.1. Similarities

- Users start as novice user at the beginning and become expert by using a system regularly (Ref. Sec. 4.1 – SUM3).

7.3.4.2. Differences

- None

7.3.4.3. Results

Users of mobile-size screen devices and desktop-size screen devices have opportunity to practice. This enables them to learn a system quickly. They may also have experience with similar platforms. This helps them to learn new applications or designs easily. This is not the case with large-size screen devices. Users do not have sufficient opportunity to practice. They also do not have opportunity to use a similar setup.

In conclusion, learning times and curves should be estimated and plans should be done according to this time and learning mechanism.

7.4. Task and Goal

7.4.1. Tasks have to be determined.

7.4.1.1. Similarities

- Mobile devices are mostly developed and used for easy usage and specialized for using applications on different physical locations (SmartInsights, 2015).

- Users can be physically mobile while completing tasks (Ref. Sec. 4.1 – STM1).

- Tasks can be completed by few interaction events (Ref. Sec. 4.1 – STM2).

- Goals are well defined (Ref. Sec. 4.1 – STM3).

- Goals are complex and long-term (Ref. Sec. 4.1 – STD3).

7.4.1.2. Differences

- Desktop-size screen devices are almost unlimited in terms of their functionality.

- The tasks on large screens are simpler and they are discrete and well defined.

7.4.1.3. Results

Mobile devices are generally designed for novice users and their interaction design is devised accordingly. This should be similar for large-size screen systems and tasks should be designed accordingly. Users of mobile devices are mobile and tasks are designed for this usage style. Large-size screen system users can use these systems while they are walking in front of the screen. There are only a few interaction events that are necessary to complete a task on mobile devices. Large-size screen systems should be similar. Goals on mobile devices and desktop devices are well defined and should be similar on large-size screen systems. Goals on desktop-size devices are complex and long term. This situation is similar on large-size screen devices. However, tasks are also complex on desktop-size screen devices whereas they should be simpler on large-size screen systems. Functionality is much more restricted on large-size screen systems.

In conclusion, large-size screen system tasks and micro tasks should be determined and human-computer interaction should be designed according to the tasks. These tasks will probably be straightforward and easy to complete.

7.4.2. Collaborative tasks should be identified.

7.4.2.1. Similarities

- Users work on the same device to complete the tasks (Ref. Sec. 4.1 – STD1).

7.4.2.2. Differences

- Tasks are designed for single user (Ref. Sec. 4.1 – DTM1).

- Goals can be readily accomplished by a single user (Ref. Sec. 4.1 – DTM2).

- Tasks are designed for a single user (Ref. Sec. 4.1 – DTD1).

- Goals can be readily accomplished by a single user (Ref. Sec. 4.1 – DTD2).

7.4.2.3. Tests

With Test 3, this guideline is validated and can be used on large-size screen systems.

7.4.2.4. Results

Users of desktop-size screen devices use the same device collaboratively to solve problems. Large-size screen system users can also do the same. However, tasks and goals are not designed for collaborative usage on mobile devices which are not suitable for large-size screen collaborative usage. This shall be considered while defining the tasks and how to complete these tasks by using collaborative interaction principles.

In conclusion, collaborative tasks and goals should be identified and new UI solutions should be proposed accordingly.

7.4.3. Task and hardware capabilities relation should be identified.

7.4.3.1. Similarities

- Desktop devices are developed and used for data entry, data retrieval and generally data management purposes and their functionalities and applications are processor-intensive (Encyclopedia.com, 2015).
- Tasks need powerful devices (Ref. Sec. 4.1 – STD2).

7.4.3.2. Differences

- Tasks can be completed with less powerful devices (Ref. Sec. 4.1 – DTM3).

7.4.3.3. Results

Desktop-size screen devices have keyboard and mouse thus they can be used to enter large amounts of data. Similarly, they have powerful processing units which are capable of handling power-intensive tasks. Large-size screen systems do not have indirect control pointing devices but they have powerful processing units. Accordingly, while learning how to complete tasks via human-computer interaction; designers should take into consideration these limitations.

In conclusion, designers need to understand the relationship between hardware capabilities and desired tasks and provide solutions according to this relationship in terms of human-computer interaction.

7.4.4. Task and screen size relation should be identified.

7.4.4.1. Similarities

- None

7.4.4.2. Differences

- On the other hand, large-size screen devices have a restricted usability area. Therefore, applications written for large screens are limited and task oriented (Pekin, İşler, & Günel, 2015).
- Tasks are designed for small size screen dynamics (Ref. Sec. 4.1 – DTM4).
- Tasks are designed for desktop size screen dynamics (Ref. Sec. 4.1 – DTD3).

7.4.4.3. Results

Tasks for mobile-size screen devices and tasks for desktop-size screen devices are designed for specific screen size dynamics. New tasks and goals are related with large-size screens and new interaction styles should be identified.

In conclusion, task and screen size relation should be identified and interaction styles should be designed accordingly.

7.5. Navigation thru Interface

7.5.1. User roles should be defined and user should be assigned for navigation thru interface for collaborative usage.

7.5.1.1. Similarities

- Only one app is active at a time so no inter app navigation occurs (Ref. Sec. 4.1 – SNM2).

7.5.1.2. Differences

- Users can navigate thru applications since no other users exist (Ref. Sec. 4.1 – DNM1).
- Users can navigate thru applications since no other users exist (Ref. Sec. 4.1 – DND1).

7.5.1.3. Results

Inter-app navigation is easily handled on both desktop and mobile devices. Large-size screen systems do not generally support such navigation. Applications are full screen most of the time and navigation do not occur between two different applications. In-app navigations may occur and this should be handled by an administrator.

In conclusion, inter-app navigations should be minimal and in-app navigations should be handled by role assignment on large-size screens.

7.5.2. Full screen usage should be promoted and no navigation among different interfaces should occur.

7.5.2.1. Similarities

- Only one application is full screen and active most of the time.
- Applications are generally full screen (Ref. Sec. 4.1 – SNM1).

7.5.2.2. Differences

- Users of such devices frequently complete different tasks with these devices thus different applications and navigation among those applications should be easy and quick (Pekin, İşler, & Günel, 2015).

- Applications are generally windowed and several navigation actions occur among them (Ref. Sec. 4.1 – DND3).

7.5.2.3. Results

Applications are almost always full screen on mobile devices and this is similar to large-size screens. Desktop devices, on the other hand, have a mixed usage of full screen applications and windowed applications. Users of these devices frequently use more than one application at a time side by side with windowing. If the users are expected to use the same UI collaboratively, applications running on large-size screens should be full screen.

In conclusion, applications and thus user interfaces should be built according to full screen display layout.

7.6. Display Organization

7.6.1. Define main visible areas.

7.6.1.1. Similarities

- Menus, notifications and similar elements are always located in the same places (Ref. Sec. 4.1 – SDM1).

- Each part of the screen is in the field of view for multi-users (Ref. Sec. 4.1 – SDD1).

7.6.1.2. Differences

- Every part of the screen is visible to all users (Ref. Sec. 4.1 – DDM1).

- Menus, notifications and similar elements are located arbitrarily on screen (Ref. Sec. 4.1 – DDD2).

7.6.1.3. Tests

With Test 4, this guideline is validated and can be used on large-size screen systems.

7.6.1.4. Results

On mobile-size screen devices, menus, notifications and other similar UI elements are located at the same location most of the time. This approach should be similar on large-size screen devices because a user may not spot an UI element since the screen is bigger than the main focus area. When several users use the same device, each of the users is easily able to see the content on desktop-size devices. This is again similar for large-size screen devices. So any UI element can be located at any place on large-size screens for visual reasons. On the other hand, only the main user can see the content on mobile-size screen devices. Other users have difficulties seeing the shared screen. Menus, notifications and other similar UI elements are located arbitrarily on screen on desktop-size screen devices which should not be followed when designing large-size screen systems.

In conclusion, the main visible areas on large-size screen systems should be defined and UI element placements should be done accordingly.

7.6.2. Define main interaction areas.

7.6.2.1. Similarities

- None

7.6.2.2. Differences

- Every part of the screen area on desktop-size screen devices is easily reachable because of the usage of pointing devices (Pekin, İşler, & Günel, 2015).

- Every part of the screen area on mobile-size screen devices is easily reachable because the screen is small and users can easily touch anywhere on screen (Pekin, İşler, & Günel, 2015).

- Every part on the screen is easily reachable (Ref. Sec. 4.1 – DDM5).

- Every part on the screen is easily reachable with a mouse for each user (Ref. Sec. 4.1 – DDD1).

7.6.2.3. Tests

With Test 4, this guideline is validated and can be used on large-size screen systems.

7.6.2.4. Results

Each part of desktop-size devices is easily reachable. Large-size screen devices are dissimilar because the larger screen means that users cannot readily reach everywhere on the screen that easily. The situation is similar for mobile-size devices too. Users of mobile-size devices can easily touch anywhere on their screen. Given this situation, it is important to define which parts of the screen are reachable for each user. Once it is defined, it is important to understand which places are better for interaction with collaborative interaction in mind.

In conclusion, main reachable locations should be identified and main interaction areas should be defined according to the reachable locations and collaborative interaction principles.

7.6.3. Understand UI Element locations.

7.6.3.1. Similarities

- Menus, notifications and similar elements are always located in the same locations (Ref. Sec. 4.1 – SDM1).

7.6.3.2. Differences

- Every part of the screen area on desktop-size screen devices is easily reachable because of the usage of pointing devices (Pekin, İşler, & Günel, 2015).

- Every part of the screen area on mobile-size screen devices is easily reachable because the screen is small and users can readily touch anywhere (Pekin, İşler, & Günel, 2015).

- UI elements are located according to single handed handheld usage ergonomics (Ref. Sec. 4.1 – DDM2).

- Every part on the screen is easily reachable (Ref. Sec. 4.1 – DDM5).

- Every part on screen is easily reachable with a mouse for each user (Ref. Sec. 4.1 – DDD1).

- Menus, notifications and similar elements are located arbitrarily on screen (Ref. Sec. 4.1 – DDD2).

7.6.3.3. Results

On mobile-size screen devices, menus, notifications and other similar UI elements are located at the same location most of the time. This approach should be similar for large-size screen devices because the user may not spot a UI element since the screen is bigger than the main focus area. Indirect controlling devices enable their users to reach every part of the screen easily on desktop-size screen devices. This is not the case for large-size screen systems where it is difficult to readily reach everywhere. Besides, if users need to use the system collaboratively, UI elements should be located according to this principle and display should be organized accordingly.

7.7. UI Element

7.7.1. New UI Elements should be designed for large screens and collaborative use.

7.7.1.1. Similarities

- None

7.7.1.2. Differences

- On the other hand, it is not possible to use the same UI elements with the same method on large screen devices (Pekin, İşler, & Günel, 2015).

- UI elements are designed for small screens (Ref. Sec. 4.1 – DEM2).

7.7.1.3. Tests

With Test 4, this guideline is validated and can be used on large-size screen systems.

7.7.1.4. Results

Most of the existing UI elements are specialized for mobile-size screen or desktop size screen usability ergonomics. They are successful when used on the related platform. However, it may be difficult to use them on large-size screen systems. The main problem is that on desktop-size screens, UI elements are designed for precise and high definition interaction methods that require a pointing device such as a mouse. These types of UI elements are not easily used when users use their bare hands. It is difficult to click on a very small sized element. It can also be difficult to use both hands on a mobile-size screen.

In conclusion, new UI elements should be designed for specific usage on large-size screen systems to enhance their potential for collaborative usage.

7.7.2. Multi-touch capabilities should be considered.

7.7.2.1. Similarities

- None

7.7.2.2. Differences

- UI elements are not available for multi-touch and thus for collaborative use (Ref. Sec. 4.1 – DEM1).

- There are specialized UI elements such as scrollable controls which can be used only by one user (Ref. Sec. 4.1 – DED1).

7.7.2.3. Results

UI elements designed specifically for mouse interaction are not generally capable of being used by multiple controllers. Scrollable or similar UI elements cannot be controlled by two people at the same time. Similarly, many UI elements are not designed to enable collaborative usage or even multi-touch, thus they are not appropriate for large-size screen systems requiring users to collaborate.

In conclusion, while designing new UI elements, multi-touch and collaborative functionalities should be considered and designed accordingly.

7.7.3. Relocation of UI Elements should be considered.

7.7.3.1. Similarities

- None

7.7.3.2. Differences

- UI elements can be dragged or repositioned for easy use (Ref. Sec. 4.1 – DEM3).

- UI elements can be dragged or repositioned for easy use (Ref. Sec. 4.1 – DED2).

7.7.3.3. Results

On mobile-size screen systems and desktop-size screen systems, UI elements are designed to be dragged to any desired location. However, on mobile-size screen systems, UI elements can only be dragged to predefined locations. On desktop-size screen systems, relocation is generally allowed to any arbitrary location. This relocation principle should be considered and possibly be restricted on large-size screen systems. Where systems are designed for multi-user environments it is most likely that users should be prohibited from relocating UI elements, as other users can find this confusing. An example of this problem is a taller user who may choose to drag a UI element to a higher location on screen where shorter users may not reach it.

In conclusion, relocation of UI elements should be considered and regulated. Designers are advised to prohibit the relocation of UI elements.

7.7.4. UI Elements should be compatible with touch interaction principles.

7.7.4.1. Similarities

- UI elements on mobile-size screen devices are designed to be large enough for a finger to fit on because of the usability and ergonomics of touch screen interaction (Park & Han, 2010).

- However, matrix style locating of UI elements should be adapted on large screen devices (Pekin, İşler, & Günel, 2015).

- UI elements are suitable for touch interaction and direct manipulation (Ref. Sec. 4.1 – SEM1).

7.7.4.2. Differences

- Double click and similar controls are more common (Ref. Sec. 4.1 – DED5).

7.7.4.3. Tests

With Test 3, this guideline is validated and can be used on large-size screen systems.

7.7.4.4. Results

Mobile-size screen systems generally use touchscreen interaction. Parallel to this, touchscreen and finger interaction principles are adapted on these devices. UI elements are created according to touchscreen interaction. Matrix style locating of UI elements is used on mobile-size screen devices. These principles should be followed while designing UI elements for large-size screens. Touch interaction and direct manipulation rules should be adapted. Double click, and scroll style controls should be minimal.

In conclusion, touchscreen interaction and direct manipulation techniques should be adapted and UI elements should be designed according to these principles.

7.7.5. Understand UI Element size and count.

7.7.5.1. Similarities

- UI elements on mobile-size screen devices are designed to be large enough for a finger to fit on because of the usability and ergonomics of touch screen interaction (Park & Han, 2010).

- UI elements are high resolution and large (Ref. Sec. 4.1 – SED1).

7.7.5.2. Differences

- UI elements can be too small for use on desktop-size screen devices since there are mouse pointers on these devices and these pointers are fairly accurate, small and do not block the vision of UI elements (Pekin, İşler, & Günel, 2015).

- Desktop-size screen devices have enough space on screen but mouse and similar interaction devices are used and this causes smaller UI elements to be used. On large screens, this cannot be used where a precise pointing device is not installed (Pekin, İşler, & Günel, 2015).

- There should be several UI elements on these devices and these UI elements should fit on the small screen (Pekin, İşler, & Günel, 2015).

- There are a small number of UI elements on screen (Ref. Sec. 4.1 – DDM3).

- Menus, notification and similar elements are generally full screen (Ref. Sec. 4.1 – DDM6).

7.7.5.3. Tests

With Test 4, this guideline is validated and can be used on large-size screen systems.

7.7.5.4. Results

For touchscreen interaction, UI elements should be suitable for finger ergonomics. Accordingly, on mobile-size screen devices, UI elements should be large enough for a single finger to fit on. Similarly, on large-size screen systems, since direct controlling interaction is used, finger ergonomics should be considered. UI element sizes and counts should be considered accordingly. If an item is used by two fingers, then size and component should be defined accordingly. Other interaction technologies such as mouse and keyboard have different dynamics. UI elements designed for specifically these types of interaction technologies cannot be directly used on large-size screen systems where mouse and keyboard are lacking. Mobile-size screen systems and desktop-size screen systems are required to have several UI elements on them for interaction because these types of devices have several purposes. Large-size screen systems, on the other hand, have few specific tasks and goals, users of these systems do not have much time to practice using them. When these issues are considered, fewer UI elements are required.

In conclusion, UI element size and number of UI elements for a specific location should be considered for a display to fit user requirements.

7.8. Feedback

7.8.1. Feedback should be visual and visible to all users.

7.8.1.1. Similarities

- Windowed feedback is given (Ref. Sec. 4.1 – SFD1).

7.8.1.2. Differences

- Feedback is given as visual and haptic besides as text based and shape change on desktop-size screen devices. Users also feel the haptic feedback received from the input device while using a mouse or keyboard (Pekin, İşler, & Günel, 2015).

- Apart from haptic feedback, audio feedback is also provided to the user whether the task is completed or not (Pekin, İşler, & Günel, 2015).

- UI element feedbacks are shown with shape changes and voices to create real manipulation effect on a real object (Pekin, İşler, & Günel, 2015).

7.8.1.3. Tests

With Test 4, this guideline is validated and can be used on large-size screen systems.

7.8.1.4. Results

Feedbacks are generally windowed on desktop-size screen devices or cover just part of the display. On mobile-size screen devices feedbacks are generally given full screen. Feedback is also frequently given in forms of haptic, audio and shape change of UI elements. Audio feedback, haptic feedback and full screen feedback cannot be given on large-size screen systems. As there may be several users, audio feedback cannot be distinguished among them. Similarly, for haptic feedback, users have to be separated and feedback should be given accordingly. This is difficult to achieve as, again, full screen feedback may disturb other users.

In conclusion, feedback should be visual and it should be visible to all users in a windowed or similar format.

7.8.2. Feedback location should be considered.

7.8.2.1. Similarities

- Visual feedback is located arbitrarily on screen (Ref. Sec. 4.1 – SFD2).

7.8.2.2. Differences

- Since every part of the screen is within focus area of humans, asynchronized and immediate feedback can be shown as full screen or located anywhere on the screen (Pekin, İşler, & Günel, 2015).

- Full screen feedback is used (Ref. Sec. 4.1 – DFM1).

7.8.2.3. Tests

With Test 4, this guideline is validated and can be used on large-size screen systems.

7.8.2.4. Results

Large-size screen system feedbacks are not advised to be full screen thus the location of windowed feedback elements should be considered. Desktop-size screen systems show feedbacks arbitrarily on the screen. Most of the time feedback occurs where the action is performed. This approach can be adapted for large-size screen systems. On mobile-size screen devices, every part of the screen is in the field of view of the user. Feedback can be shown anywhere on mobile-size screen devices. However, on large-size screen systems, users may miss the feedback since it is out of their visual area.

In conclusion, feedback should be given to users either at fixed positions that are dedicated to feedback or at locations where related actions are performed.

7.8.3. Which apps can give feedback should be considered.

7.8.3.1. Similarities

- Feedback is always related to the active app (Ref. Sec. 4.1 – SFM1).

7.8.3.2. Differences

- None

7.8.3.3. Results

On mobile-size screen systems, only active apps give feedback to the users. Sometimes background apps can give some feedback info but these situations are small in number. On large-size screen systems, where it is desirable to have a single active app displayed at any one time, other apps should not be disruptive.

In conclusion, only the active full screen app should be allowed to give feedback to the collaborative users of large-size screen systems.

7.8.4. Audio, haptic and other types of feedback should be considered.

7.8.4.1. Similarities

- None

7.8.4.2. Differences

- Feedback is given as visual and haptic besides as text based and shape change on desktop-size screen devices. Users also feel the haptic feedback received from input device while using a mouse and keyboard (Pekin, İşler, & Günel, 2015).

- Apart from haptic feedback, audio feedback is also provided to the user whether the task is completed or not (Pekin, İşler, & Günel, 2015).

- UI element feedbacks are shown with shape changes and voices to generate a real manipulation effect on a real object (Pekin, İşler, & Günel, 2015).

- Sound feedback is used (Ref. Sec. 4.1 – DFM2).

- Sound feedback is used (Ref. Sec. 4.1 – DFD1).

- Haptic feedback is provided by the mouse and keyboard (Ref. Sec. 4.1 – DFD2).

7.8.4.3. Results

Audio, haptic, textual feedbacks, shape change of UI elements and other types of feedbacks are frequently used on mobile-size screen and desktop-size screen devices. These devices are generally created for singular use and feedbacks are related with the existing user each time. On the other hand, large-size screen systems can be used by several users simultaneously. Audio feedback may not be efficient in such an environment since the noise created by the system can be received by every user. Similarly vibrating or similar haptic feedback may not be targeted optimally. Thus to create personal or dedicated feedback, feedback elements should be visual and visible to the related user.

In conclusion, audio, haptic and other types of feedbacks may not be appropriate for large-size screen systems as they may lead to confusion among users.

CHAPTER 8

DISCUSSION

In this chapter, the findings of the study are discussed. The contribution of the study, the answers to the questions, realisms of hypotheses, comparison to the existing knowledge and further research possibilities are presented in the following five subsections.

8.1. Differences and Similarities of Large-Size Screens

As set out in the Introduction, desktop-size screen systems and mobile-size screen systems have several similarities and differences to large-size screen systems. These differences and similarities had not been identified systematically. After an initial review of existing studies, we defined some of the differences and similarities between large-size screen systems and mobile-size screen systems and desktop-size screen systems. This study has been published in the journal “Deniz Bilimleri ve Mühendisliği Dergisi”. The differences and similarities are categorized into seven categories. Each category is explained in detail in the related section. By using these differences and similarities, we have proposed initial design ideas and proposals for large-size screen systems. These ideas and proposals are given below:

8.1.1. Interaction Style & Data Entry Differences and Similarities

When all issues are considered, different ways of interaction are necessary for large-size screen systems when compared to desktop-size screen devices. A direct manipulation interaction style seems to be suitable for large-size screen systems, especially where collaboration among multiple users is desired.

Data entry is the main input ability of users to provide interaction and varies according to the usability of the system. Systems can be fed by users only if data entry is present on interactive environments. When human-computer interaction is considered, improving interaction performance and facilitating usability are dependent on viable systems design (Card, Moran, & Newell, 1980). Accordingly, design should be undertaken specifically for large-size screen devices to enhance their reliability, usability and ease of data entry. While designing data entry functionalities, screen properties should also be considered. We have found several differences in the data entry process used on large-size screens. These differences are studied according to the screen properties.

Gestural interaction is one of the most important input techniques used on large-size screens. This technique is also used on mobile-size screen devices in games (MildMania, 2015) and is suitable for large-size screens. Using such alternative input techniques on large-size screens is easier and more user friendly. On desktop-size screen devices however, such techniques are not required since there are several third party interaction elements already employed. Besides, trying to perform gestures with a mouse is not easy for users and feels unnatural since touch-available screens are not typical on these devices.

8.1.2. User Skill Level Differences and Similarities

Large-size screen device users can be inexperienced or not familiar with the interaction style and user interface. However, they are expected to have knowledge about the domain and content. If we look at the user profile, users of these systems have a general level of computer knowledge, may be expert on the content, but may be unfamiliar with the interaction style and user interfaces. When we examine skill levels, users of mobile-size screen devices tend to be more experienced with the user interface and less experienced with the content, users of desktop-size devices are more experienced in terms of user interface and content, while users of large-size screen devices are less experienced in terms of user interface and interaction but tend to be more experienced in relation to the content. This differentiation is the main difference among these users. It should also be noted that large-size screen device users have limited opportunity to practice and improve their skills as such systems are not readily available and users do not have access to them all of the time.

8.1.3. Task and Goal Differences and Similarities

Large-size screen devices, in general, are developed and used for data presentation and ease of data distribution. Besides, these devices are also targeted to let their users use them simultaneously and collaboratively. Especially in the case of collaborating users, there are several other usability differences that arise in terms of large-size screen devices.

8.1.4. Navigation thru Interface Differences and Similarities

Vivid navigation functionality is not necessary on large-size screen devices since the applications run full screen and only a single application is aimed to run with these devices. Thus there is no reason for supporting a dedicated navigation option among applications on large-size screen devices. When we consider that more than one person can use these systems, the problem of who is going to handle navigation occurs and this creates an authorization issue. Even though the navigation functionality requirement is low there is still need for a different structure for similar purposes on large-size screen systems. Designers should consider that navigation among applications and in application should be as low as possible for such systems and designs should be completed with this in mind.

8.1.5. Display Organization Differences and Similarities

When we consider average arm reach (Capderou, Berkani, Becquemin, & Zelter, 2011) and work on large-size screen devices, UI elements should be placed where users can easily reach them. Designers should take into account that users cannot reach everywhere on the screen from where they are standing. Accordingly, when users are stationary in front of the screen, the UI elements should be located near to them. On the other hand, when the users are moving, the UI elements should be located where the last interaction occurs.

When screens are large, actions occurring in the system should be within the user's attention area (Eriksen & James, 1986). Since mobile-size screens are small enough to stay in the focus area of users, there is no need to do anything special for this concern. Similarly, as desktop-size screens are small enough to fit in a human's focus area, UI elements and other properties can be located anywhere on the screen. However, on large-size screens, the screen area means that any UI element can easily be out of the visible area, or users can miss an event occurring within a short time. When all these issues are taken into account, actions should be located within the user's focus area (Eriksen & James, 1986) on the screen and display organization should be done according to this principle.

8.1.6. UI Element Differences and Similarities

UI element differences are critical design issues as they have to be considered when designing the UI elements for large-size screen systems such as whether an element will be activated with a single or double click, its size on the display, usage and visual differences. Thus, firstly, designers need to understand the UI element requirements of the specific large-size screen system they are working with.

8.1.7. Feedback Differences and Similarities

In their work, Burckhardt et al. (Burckhardt, et al., 2013) state that feedback design is a topic that has to be handled with care while designing user interfaces, since it affects usability and the learning of systems. When sufficient feedback is given to the user, correct usage of systems and shorter learning curves are obtained. According to our survey, when adequate and correct feedback is given to the user, even inexperienced users can learn and use the system. To complete user interface designs, designers should consider feedback mechanisms. When screen sizes are considered, different systems have different feedback mechanisms and large-size screen systems often require a separate feedback mechanism.

8.2. Existing Guidelines and Principles Comparisons

To provide design guidelines and principles for large-size screen systems, we initially reviewed existing design guidelines and principles for mobile-size and desktop-size screen systems. We compared these guidelines and provided suggestions for large-size screen systems. Our general approach in defining guidelines and principles is to focus on UI elements and provide suggestions for each of them. Accordingly, our suggestions are given below:

8.2.1. Navigation Elements / Bars

Navigation Elements (Microsoft) / Bars (Apple) are generally used for navigation purposes. However, collaborative large-size screen systems are not generally built or designed to include such functionality in their applications. Thus we do not provide any specific guidelines or principles for including navigation elements or status bars for collaborative large-size screen systems.

8.2.2. Content Elements / Content Views

As there are similarities in both Apple and Microsoft guidelines, we decided to categorize similar items as “Visual Elements”. Accordingly, any UI element that is responsible for providing information to the users are located in “Visual Elements”. “Visual Elements” should be visible to each individual user for collaborative usage. They should also be large enough for users who are located further away to see them easily. Again, if a “Visual Element” is targeted to a single user or a group of users, then it must be specifically expressed.

8.2.3. Command Elements / Controls

The command elements of Microsoft and control elements of Apple have very much in common. Large-size screen systems also have similar UI elements. We elected to refer to these as “Interaction Elements”, we generally use the most of the guidelines and principles declared by both companies. Some extra suggestions are added for each group separately in section 5.2.3.3 of this document.

8.2.4. Temporary Views

Large-size screen systems also need temporary view functionality thus this type of UI element can be used on large-size screen systems. We refer to these as “Feedback Elements” in this study. Alerts are generally used to notify the user about any concurrent event. The guidelines generally cover the important parts. However, the size of the screen affects some important aspects. Accordingly, the location of the alert should be carefully chosen. Notifying the desired user is important. Action sheets and modal views are not necessarily used on large-size screens however if they are needed, similar corrections and adaptations should be undertaken.

8.3. Laboratory Experiments

A laboratory experiment to test several aspects of large-size screen systems and collaborative usage on large-size screen systems was necessary. This study has also been published in the journal “International Journal of Human Computer Interaction”. We have created an environment to systematically test the uncertain and ambiguous parts of collaborative usage of large-size screen systems. Four tests were created and applied to 30 people. Results are given in the related section. Discussion for the results of each test is provided below:

8.3.1. Test 1 – Direct vs. Indirect Control Pointing Devices on Large-Size Screen Systems

In Test 1, we mainly compared indirect interaction and direct interaction on large-size screen systems. We asked the users to complete a task first by using a mouse and second by using the touchscreen individually. We have collected user interaction points, interaction time and error counts. Statistical analysis shows that there are meaningful differences between the usage of direct interaction and indirect interaction methods.

According to this, accuracy of mouse and touchscreen statistically differ on large-size screen systems. MSCDiff and TSCDiff in pixels are measured 45.78 ± 21.59 and 35.33 ± 17.17 respectively. This result shows that touchscreen interaction is more accurate on large-size screen systems. Thus we can say that if accuracy is required, touchscreen interaction should be chosen on large-size screen systems.

Usage time also statistically differ on large-size screen systems by mouse and touchscreen. MHT and THT in milliseconds are measured with a mean of 1085 ± 238 and 1833 ± 705 respectively. This shows us that the hit time of a target is smaller when a mouse is used. This time includes the walking time of the user from one location to another location in front of a large-size screen.

Error count is also significantly different between mouse and touchscreen. Users made errors with 1, 2 and 3 on mouse and 1 and 2 on touchscreen. Error counts also are smaller on touchscreen than mouse. Thus if less error is required on such systems, then touchscreen interaction should be considered.

When the results of Test 1 are analyzed, serious games and similar systems should choose direct interaction methods among two interaction types. These applications should be used with higher accuracy and less error. Speed is also important, but not as much as the others, since these applications require some thinking time before an interaction is performed.

With this test, we can conclude that "Direct-control pointing devices should be used" and "Direct manipulation should be adapted" guidelines can be created.

8.3.2. Test 2 – Single User vs. Multiple User without Collaborative Task on Large-Size Screen Systems

In Test 2, we mainly compared single user usage with multiple user usage. We asked the users to complete a task first by themselves and then in a group. We have collected user interaction points, interaction time and error counts. Statistical analysis shows that there are meaningful differences between the usages of single user and multiple users. We have statistically analyzed the comparison of individual users to all groups and to their own group.

Accordingly, individual mouse click accuracy significantly differed from group touch accuracy. Mean of IMSCDiff is higher than the mean of GTSCDiff with values 45.78 ± 21.60 and 39.86 ± 19.24, respectively. Similarly, the accuracy of touchscreen statistically differs between individual and group usage on large screen systems. Mean of ITSCDiff is lower than the mean of GTSCDiff with values 35.33 ± 17.17and 39.86 ± 19.24, respectively. This shows that the accuracy is higher for group usage than individual mouse and individual touchscreen usages. Therefore, if several users use a system simultaneously, accuracy will be higher with touchscreen and systems can be designed accordingly.

Usage time also statistically differs on large screen systems by mouse and touchscreen. Mean of IMHT is lower than the mean of GTHT with values 1085 ± 238 and 1297 ± 511, respectively. This shows that mouse usage is faster on large screen systems; however, the difference is as low as 200 milliseconds which is negligible. The difference was higher for individual usage, where mean of ITHT is higher than the mean of GTHT with values 1833 ± 705 and 1297 ± 511, respectively. Therefore, when a large screen is used by several users simultaneously, touchscreen is nearly as good as mouse interaction in terms of time.

Error count is not significantly different between individual and group users.

In the second part of the analysis for Test 2, we compared each user with their own group. Accordingly, accuracy was very different among the users; i.e., some users significantly differed from other individuals in their own group. However, considering the hit times, almost every user performed statistically significantly differently than their own group. Therefore, we can say that group usage is different to individual usage. Error count, on the other hand, was not statistically different for any of the individuals than their group. So, we cannot make any comment on this in general.

With this test, we can conclude that "Touchscreen is the best, multi-touch is necessary" and "Collaborative usage should be considered" guidelines can be created.

8.3.3. Test 3 – Collaborative Usage Effectiveness on Large-Size Screen Systems

In Test 3, we mainly compared singular usage with collaborative usage. We asked the users to complete a collaborative task first by themselves and second in a group. We have collected UI element choices, item movement, item rotation and item zoom. Statistical analysis shows that there are meaningful differences between singular and collaborative usage with the use of non-collaborative and collaborative menu elements. We have statistically analyzed comparison of these differences separately.

Firstly, we compared menu interaction with direct manipulation in individual usage. Difference is statistically significant on all move, rotate and zoom actions. Accordingly, users tend to use direct manipulation for large screen specific collaborative tasks.

Collaborative usage of several users also differs significantly for the above actions. Users again prefer to use collaborative UI elements on large screen systems for collaborative tasks.

When we compared singular usage and collaborative usage of menu interaction, we could not find statistically significant differences.

When we look at usage of collaborative UI elements, there is a significant difference between singular usage and collaborative usage for direct manipulation. Accordingly, when users use the system collaboratively, they are much more comfortable with the system and use the system more actively.

When we look at the overall success rate, collaborative usage differs statistically significantly to singular usage. Collaborative usage leads to more successful results in terms of total hit for the same time period. Median values for total hit of items are 7 and 25.5, respectively for singular and collaborative usage. We can say that collaborative tasks can be completed better by collaborating users on large touch screens. However, since 5 users were grouped as a group, we would expect a 5 times better result, however the result shows that there is only a 4 times increase in performance.

When we examine the actions for collaborative usage, we see that, for movement there is not any significant difference between menu and direct manipulation choices. Therefore, we cannot conclude anything from this. Similarly, we cannot make any judgment in terms of rotate action, since none of the users used a rotate action with the menu on collaborative usage. However, scale action significantly differed between singular and collaborative usage according to the scale factor. When an item's scale needs to be changed by a large factor, users chose to use the menu and when the scale factor needed was small, users chose direct manipulation. Thus, for scale, the value makes a difference.

With this test, we can conclude that "There should be sufficient surface for each user to see the content", "User collaboration phenomenon should be understood", "Collaborative tasks should be identified" and "UI Elements should be compatible with touch interaction principles" guidelines can be created.

8.3.4. Test 4 – UI Element Location and Size on Large-Size Screen Systems

In Test 4, we analyzed the preferences of participants for UI element locations. We asked the users to choose the most appropriate position for visual, interaction and feedback UI elements. We have collected their preferences for each UI element separately. Statistical analysis shows that there are meaningful differences among the preferences of the users. 50% of users preferred the visual UI elements to be aligned to the top center. 17% preferred them to be attached to the active character on screen. 33% of the users chose the visual UI elements to be free and that users can drag them to an appropriate position in real time. For the interaction UI elements, users equally preferred them to be aligned to the bottom, attached to the active character and free and draggable. So there is no consensus on the location of the interaction element. In terms of feedback elements, all of the users preferred the free mode and chose the UI elements to be located at the center of the screen.

With this test, we can conclude that "Define main visible areas", "Define main interaction areas", "Understand UI Element locations", "Feedback should be visual and visible to all users", "Feedback location should be considered" and "New UI Elements should be designed for large screens and collaborative use" guidelines can be created.

8.3.5. Questionnaires

In the questionnaires, participants in the tests were asked a series of survey questions as soon as they completed the tests. The questions were all about usability and human- computer interaction. All the questions were answered with a Likert scale from 1-5. Answers to the questions are shown in Sec. 6.9 with percentages in a tabular form. According to the results, system seems to be working correctly and the tests are legitimate. For the questionnaire “User Interface Satisfaction” participants generally said that system is satisfying in terms of user interfaces. Some of the participants said that the system is weak in giving feedback to the user. It is also valid for error messages and help messages. Looking at this, we can conclude that feedbacks are not successful and have to be given at the center of the screen to be recognized by the users. For the second questionnaire, “Perceived Usefulness and Ease of Use”, users generally said that the system is not useful for everyday life but it would be easier to use the system if necessary. This shows that large-size screen systems have to be designed for specific purposes and user needs should be at the center of the design process. On the other hand, it seems that collaborative usage would be easier for such systems. For the third questionnaire, “NASA Task Load Index”, participants generally said that using the system is physically demanding since the screen is beyond human reach and users have difficulties while using the system. Collaboration can decrease the work load and better collaborative tasks have to be designed for such systems. As the last questionnaire, “Nielsen's Attributes of Usability”, the system seems to be learned and used easily and such large-size systems should be accepted easily by users if available. On the other hand, users stated that better feedback and error handling is necessary.

8.4. Guidelines and Principles for Large-Size Screen Systems

According to the results, we can suggest that designers of large-size collaborative systems can benefit from the new guidelines defined in this study. These guidelines can be used as a basis when creating large-size screen systems. To the best of our knowledge, this is the first study testing the collaborative usage of large-size touchscreen systems in a laboratory environment and that has used the results to prepare design guidelines and principles. Designers or engineers can directly use the derived guidelines and principles produced by our study. There are similar studies that try to address collaboration issues on multi-user systems and they have interesting results similar to ours. A study by Sarmiento and Stahl (Sarmiento & Stahl, 2008) investigates collaborative usage for creative activity. They found that collaborative working occurs in three stages; indexical referencing, group remembering and bridging across discontinuities. These have similarities with our findings. The core idea of collaboration with these systems suggested the need to create guidelines with task specific problems in mind. Similarly, their study suggests that a synergy environment can only be created with collaborative usage. We also found that this is the situation in our case and our Test 2 and Test 3 show the differences in the synergy environment. Synergy is created only if the task is collaborative and users try to solve the creative tasks collaboratively. Another study by Chorianopoulos (Chorianopoulos, 2008) provides a series of design guidelines for large-size screens. These guidelines are given as a list of high-level and generic design factors. Our final guidelines provide some differences in terms of control.

Those guidelines provide information for singular use. However, our guidelines focus on collaborative usage. As an example, their guidelines promote relaxed navigation whereas our guidelines minimize the use of navigation. With this in mind, we can conclude that each specific system may need a specific design guideline independent of the form factor.

8.5. Applications of Large-Size Screen Systems

Large-size screen systems are widely used for various purposes currently. Some example usage areas span communicative working, information presenting, virtual presence, serious games, military purposes and similar areas. New areas and undiscovered possibilities also exist. Our study may also lead to more targeted solutions for different usability areas.

A very well applied area for using large-size screen systems is collaborative and communicative working and studying. One of the most known examples is Microsoft Surface (Microsoft, 2017). Microsoft worked on this system for a long time and matured the technology to a level where it can be used practically. It supports built-in office programs for teamwork. Applications are optimized for large-size screens and collaborative work. Liveboard (Elrod, et al., 1992) is a system specifically designed for virtual collaboration on large-size screens and enables collaborating users to work or study on large-size screens simultaneously. This type of application is generally used for office applications. Sharing the same content and interacting with the same thing is problematic and our solution may lead to better design solutions for such systems.

Another well suited area for large-size screen systems is entertainment. Museums, exhibitions, games and shows are popular locations for large-size screens. Several users can interact with the content simultaneously in museums and exhibitions. Broadcast AR (Inde, 2017) system is an augmented reality large-size screen system used for providing virtual content on a large scale. The system provides cinematic augmented reality experience on large-size screens. A study by Ardito et. al. (Ardito, Buono, Costabile, & Desolda, 2015) observes the usage of virtual interactive mannequins on large-size screens. Large-size screen technology is also used for interactive commercial systems. It is possible to find better design solutions for large-size interactive systems collaboratively. Our study can be used to find such interaction solutions for collaborative commercial applications.

Large-size screen systems are already being used for educational purposes. Fatih Project uses large-size screens (Meb, 2017) in schools in Turkey. The project is still extending and new additions are being included such as distributed solutions. Using large-size screen systems for educational purposes has already been tested empirically. Lanzilotti et. al. studied collaborative interaction around a large-size screen with pupils (Lanzilotti, Ardito, Costabile, De Angeli, & Desolda, 2015). Our study can also be used for the design of such solutions by reference to the collaborative guidelines and principles.

Large-size screen systems have considerable potential to be used for military purposes and serious games. Such applications are generally used by several users simultaneously. High precision and fast response are key features and it is very critical to solve the problem of multi-user action. The Simsoft company created a serious game for training military staff and presented it at IDEF'15 (Simsoft, 2017). The system enables 60 concurrent users to play a serious game for training purposes. Other examples cover training firefighters, police and emergency responders. Defining most efficient interaction for multi-user collaboration is crucial for serious games. Our guidelines and principles can be used for designing such systems.

As discussed above, usage areas and applied platforms are various and can be further extended. In any case, the core ideas stay the same and the methodology is already defined in the scope of this thesis.

CHAPTER 9

CONCLUSION

This study set out to develop a systematic approach towards HCI on collaborative large-size touchscreen systems. Existing studies were reviewed to obtain necessary background and to inform the research methodology. Thereafter, a prototype system was built to enable users to test the system in a controlled laboratory environment. The interaction data was collected quantitatively and collaboration was recorded. Differences and similarities between existing systems and large-size screen systems were defined. Existing design guidelines and principles were examined and relevant ones were identified. A laboratory experiment of four major tests was applied to volunteer participants. Surveys and questionnaires about the system and tests were applied to the participants. Statistical analysis and discussion of the findings was undertaken. Together these findings yield the creation of new design guidelines and principles for designing collaborative large-size screen systems.

The research compared differences and similarities in usability among mobile-size screen devices, desktop-size screen devices and large-size screen devices. Screen size and usage have led to differentiated design approaches between these platforms, however specific approaches were missing for large-size screens in terms of user interfaces and human-computer interaction. A series of tests and laboratory experiments showed that users of large-size screen systems tend to use direct control pointing devices rather than indirect control pointing devices. Significantly, they prefer using a large-size display system collaboratively and felt that collaborative tasks are more suitable for large-size screen systems. They also choose to use UI elements that are more suitable for collaborative interaction and UI element locations that are different to those in mobile-size and desktop-size screen systems. According to the users, collaborative tasks are more suitable for large-size screen systems.

Our study produced a set of design guidelines and principles for the design of HCI elements on large-size touchscreen systems. As a result of all the findings, designers should consider the screen size and whether the collaborative usage is usable for the system they are designing. If these issues are suitable for their system, they can use the major findings of this study.

We have made a series of empirical studies at several stages throughout the study. Finally, we have proposed a research method for our study, defined how large-size screen systems are different in terms of various aspects, compared existing design guidelines and principles for well-known platforms, tested users' performance in real life laboratory conditions and created new design guidelines and principles for designing human-computer interaction for large-size screen systems. These guidelines and principles can be extended by including several other aspects of large-size screen systems just like viewing distance, virtual presence and sound integration. Another extension may be building a system with the findings in hand and providing a complete solution for large-size screen systems. This final result may contain several other aspects of HCI such as UI element design, gestural interaction, multi-presence and virtual reality.

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APPENDICES

APPENDIX A

QUESTIONNAIRE for USER INTERFACE SATISFACTION

OVERALL REACTION TO THE SOFTWARE								
1.		terrible						wonderful
2.		difficult						easy
3.		frustrating						satisfying
4.		inadequate power						adequate power
5.		dull						stimulating
6.		rigid						flexible
SCREEN								
7.	Organization of information	confusing						very clear
8.	Sequence of screens	confusing						very clear
TERMINOLOGY AND SYSTEM INFORMATION								
9.	Use of terms throughout system	inconsistent						consistent
10.	Terminology related to task	never						always
11.	Position of messages on screen	inconsistent						consistent
12.	Prompts for input	confusing						clear
13.	Computer informs about its progress	never						always

14.	Error messages	unhelpful						helpful
LEARNING								
15.	Learning to operate the system	difficult						easy
16.	Exploring new features by trial and error	difficult						easy
17.	Remembering names and use of commands	difficult						easy
18.	Performing tasks is straightforward	never						always
19.	Help messages on the screen	unhelpful						helpful
SYSTEM CAPABILITIES								
20.	System speed	too slow						fast enough
21.	System reliability	unreliable						reliable
22.	System tends to be	noisy						quiet
23.	Correcting your mistakes	difficult						easy
24.	Designed for all levels of users	never						always

APPENDIX B

PERCEIVED USEFULNESS and EASE of USE QUESTIONNAIRE

PERCEIVED USEFULNESS								
1.	Using the system in my job would enable me to accomplish tasks more quickly	unlikely						likel y
2.	Using the system would improve my job performance	unlikely						likel y
3.	Using the system in my job would increase my productivity	unlikely						likel y
4.	Using the system would enhance my effectiveness on the job	unlikely						likel y
5.	Using the system would make it easier to do my job	unlikely						likel y
6.	I would find the system useful in my job	unlikely						likel y
PERCEIVED EASE OF USE								
7.	Learning to operate the system would be easy for me	unlikely						likel y
8.	I would find it easy to get the system to do what I want it to do	unlikely						likel y
9.	My interaction with the system would be clear and understandable	unlikely						likel y
10.	I would find the system to be flexible to interact with	unlikely						likel y
11.	It would be easy for me to become skillful at using the system	unlikely						likel y
12.	I would find the system easy to use	unlikely						likel y

APPENDIX C

NIELSEN'S ATTRIBUTES of USABILITY QUESTIONNAIRE

PERCEIVED EASE OF USE								
1.	Learnability	bad						good
2.	Efficiency	bad						good
3.	Memorability	bad						good
4.	Errors (Accuracy)	bad						good
5.	Subjective Satisfaction	bad						good

APPENDIX D

NASA TASK LOAD INDEX

NASA Task Load Index								
1.	Mental Demand How mentally demanding was the task?	very low						very high
2.	Physical Demand How physically demanding was the task?	very low						very high
3.	Temporal Demand How hurried or rushed was the pace of the task?	very low						very high
4.	Performance How successful were you in accomplishing what you were asked to do?	perfect						failure
5.	Effort How hard did you have to work to accomplish your level of performance?	very low						very high
6.	Frustration How insecure, discouraged, irritated, stressed, and annoyed were you?	very low						very high

APPENDIX E

INTERVIEW QUESTIONS

1.	Age:				
2.	Sex:	☐ Male	☐ Female		
3.	Education:	☐ Lower	☐ High School	☐ University	☐ Higher
4.	Profession:	☐ IT Related	☐ Art Related	☐ Other	
5.	Experience duration: (In terms of HCI)	☐ 0-5 years	☐ 5-10 years	☐ More	

Next set of questions shall be answered for usability of the system instead of the content itself. For example, zooming in and out, selecting, data entry and panning.

6.	Did you have difficulties while completing tasks? If so, please explain. Do you have suggestions for solutions?
7.	Does the screen size have advantage or disadvantage for collaborative usage?
8.	Do you have any further suggestions on usability?

APPENDIX F

TEST 1 STATISTICAL ANALYSIS TABLES

One-Sample Kolmogorov-Smirnov Test

		MSCDIF	TSCDIF	MSDIF	MHITTIME	THITTIME
N		1620	1620	1620	1620	1620
Normal Parameters[a,,b]	Mean	45,7800968	35,3335877	2252,245433	1085,05123	1833,74
	Std. Deviation	21,59516201	17,16643308	1,0379955E3	237,621143	704,582
Most Extreme Differences	Absolute	,043	,041	,120	,068	,056
	Positive	,043	,041	,086	,068	,056
	Negative	-,025	-,029	-,120	-,043	-,054
Kolmogorov-Smirnov Z		1,714	1,663	4,834	2,746	2,253
Asymp. Sig. (2-tailed)		,006	,008	,000	,000	,000

a. Test distribution is Normal.

b. Calculated from data.

Ranks

		N	Mean Rank	Sum of Ranks
TSCDIF - MSCDIF	Negative Ranks	1044[a]	884,83	923766,00
	Positive Ranks	576[b]	675,77	389244,00
	Ties	0[c]		
	Total	1620		

a. TSCDIF < MSCDIF

b. TSCDIF > MSCDIF

c. TSCDIF = MSCDIF

Test Statistics[b]

	TSCDIF - MSCDIF

Z	-14,192[a]
Asymp. Sig. (2-tailed)	,000

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
MHT - THT	Negative Ranks	1463[a]	866,18	1267216,00
	Positive Ranks	150[b]	229,83	34475,00
	Ties	7[c]		
	Total	1620		

a. MHT < THT

b. MHT > THT

c. MHT = THT

Test Statistics[b]

	MHT - THT
Z	-32,944[a]
Asymp. Sig. (2-tailed)	,000

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
MEC * TEC	1620	99,9%	1	,1%	1621	100,0%

MEC * TEC Crosstabulation

			TEC			
			0	1	2	Total
MEC	0	Count	1486	58	1	1545

		% within MEC	96,2%	3,8%	,1%	100,0%
		% within TEC	96,1%	80,6%	100,0%	95,4%
		% of Total	91,7%	3,6%	,1%	95,4%
	1	Count	57	13	0	70
		% within MEC	81,4%	18,6%	,0%	100,0%
		% within TEC	3,7%	18,1%	,0%	4,3%
		% of Total	3,5%	,8%	,0%	4,3%
	2	Count	4	0	0	4
		% within MEC	100,0%	,0%	,0%	100,0%
		% within TEC	,3%	,0%	,0%	,2%
		% of Total	,2%	,0%	,0%	,2%
	3	Count	0	1	0	1
		% within MEC	,0%	100,0%	,0%	100,0%
		% within TEC	,0%	1,4%	,0%	,1%
		% of Total	,0%	,1%	,0%	,1%
Total		Count	1547	72	1	1620
		% within MEC	95,5%	4,4%	,1%	100,0%
		% within TEC	100,0%	100,0%	100,0%	100,0%
		% of Total	95,5%	4,4%	,1%	100,0%

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
MSCDIF	1620	126,58969	1,41421	128,00390	45,7800968	21,59516201
TSCDIF	1620	113,49031	,81599	114,30630	35,3335877	17,16643308
MEC	1620	3	0	3	,05	,237
TEC	1620	2	0	2	,05	,212

MSDIF	1620	4355,9459	271,5291	4627,4750	2252,245433	1,0379955E3
MHT	1620	4651,000	599,000	5250,000	1085,05123	237,621143
THT	1620	4183	616	4799	1833,74	704,582
Valid N (listwise)	1620					

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	56,350[a]	6	,000
Likelihood Ratio	27,439	6	,000
Linear-by-Linear Association	37,085	1	,000
N of Valid Cases	1620		

a. 9 cells (75,0%) have expected count less than 5. The minimum expected count is ,00.

APPENDIX G

TEST 2 STATISTICAL ANALYSIS TABLES

One-Sample Kolmogorov-Smirnov Test

		IMSCDiff	ITSCDiff	IMHT	ITHT	GTSCDiff	GTHT
N		1620	1620	1620	1620	324	324
Normal Parameters[a,,b]	Mean	45,780097	35,3335877	1085,05	1833,74	39,863804	1296,54
	Std. Deviation	21,5951620	17,16643308	237,621	704,582	19,2403727	511,224
Most Extreme Differences	Absolute	,043	,041	,068	,056	,058	,216
	Positive	,043	,041	,068	,056	,058	,216
	Negative	-,025	-,029	-,043	-,054	-,040	-,160
Kolmogorov-Smirnov Z		1,714	1,663	2,746	2,253	1,048	3,889
Asymp. Sig. (2-tailed)		,006	,008	,000	,000	,222	,000

a. Test distribution is Normal.

b. Calculated from data.

Ranks

		N	Mean Rank	Sum of Ranks
IMSCDiff - GTSCDiff	Negative Ranks	132[a]	145,65	19226,00
	Positive Ranks	192[b]	174,08	33424,00
	Ties	0[c]		
	Total	324		

a. IMSCDiff < GTSCDiff

b. IMSCDiff > GTSCDiff

c. IMSCDiff = GTSCDiff

Test Statistics[b]

	IMSCDiff - GTSCDiff
Z	-4,207[a]
Asymp. Sig. (2-tailed)	,000

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
ITSCDiff - GTSCDiff	Negative Ranks	199[a]	181,89	36197,00
	Positive Ranks	125[b]	131,62	16453,00
	Ties	0[c]		
	Total	324		

a. ITSCDiff < GTSCDiff

b. ITSCDiff > GTSCDiff

c. ITSCDiff = GTSCDiff

Test Statistics[b]

	ITSCDiff - GTSCDiff
Z	-5,850[a]
Asymp. Sig. (2-tailed)	,000

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
IMHT - GTHT	Negative Ranks	214[a]	175,35	37524,50
	Positive Ranks	105[b]	128,72	13515,50

		N
	Ties	5[c]
	Total	324

a. IMHT < GTHT

b. IMHT > GTHT

c. IMHT = GTHT

Test Statistics[b]

	IMHT - GTHT
Z	-7,282[a]
Asymp. Sig. (2-tailed)	,000

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
ITHT – GTHT	Negative Ranks	86[a]	126,75	10900,50
	Positive Ranks	234[b]	172,90	40459,50
	Ties	4[c]		
	Total	324		

a. ITHT < GTHT

b. ITHT > GTHT

c. ITHT = GTHT

Test Statistics[b]

	ITHT - GTHT
Z	-8,923[a]
Asymp. Sig. (2-tailed)	,000

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

APPENDIX H

COMPARISONS of DIFFERENCES for TEST 2

MSCDIFF

	Individual (□̄ ± □) n=54	Group (□̄ ± □) n=54	p
Participant1-Group1	43.31 ± 20.77	40.99 ± 22.14	0.556
Participant2-Group1	45.82 ± 21.13	40.99 ± 22.14	0.219
Participant3-Group1	57.06 ± 24.39	40.99 ± 22.14	<0.05*
Participant4-Group1	50.02 ± 24.68	40.99 ± 22.14	0.063
Participant5-Group1	36.33 ± 18.94	40.99 ± 22.14	0.247

*Significant at p <0.05

TSCDIFF

	Individual (□̄ ± □) n=54	Group (□̄ ± □) n=54	p
Participant1-Group1	32.51 ± 13.90	40.99 ± 22.14	<0.05*
Participant2-Group1	23.49 ± 14.08	40.99 ± 22.14	<0.05*
Participant3-Group1	50.72 ± 16.37	40.99 ± 22.14	<0.05*
Participant4-Group1	28.16 ± 16.99	40.99 ± 22.14	<0.05*
Participant5-Group1	25.23 ± 9.84	40.99 ± 22.14	<0.05*

*Significant at p <0.05

MSCDIFF

	Individual ($\bar{\square} \pm \square$) n=54	Group ($\bar{\square} \pm \square$) n=54	p
Participant1-Group2	45.08 ± 21.42	40.28 ± 24.20	0.296
Participant2-Group2	48.75 ± 21.92	40.28 ± 24.20	0.095
Participant3-Group2	41.96 ± 21.46	40.28 ± 24.20	0.705
Participant4-Group2	53.25 ± 23.46	40.28 ± 24.20	<0.05*
Participant5-Group2	45.52 ± 22.33	40.28 ± 24.20	0.281

*Significant at p <0.05

TSCDIFF

	Individual ($\bar{\square} \pm \square$) n=54	Group ($\bar{\square} \pm \square$) n=54	p
Participant1-Group2	36.23 ± 13.03	40.28 ± 24.20	0.291
Participant2-Group2	53.31 ± 20.20	40.28 ± 24.20	<0.05*
Participant3-Group2	22.11 ± 11.51	40.28 ± 24.20	<0.05*
Participant4-Group2	42.95 ± 15.44	40.28 ± 24.20	0.483
Participant5-Group2	46.87 ± 17.66	40.28 ± 24.20	0.097

*Significant at p <0.05

MSCDIFF

	Individual ($\bar{\square} \pm \square$) n=54	Group ($\bar{\square} \pm \square$) n=54	p
Participant1-Group3	53.58 ± 25.20	37.20 ± 17.46	<0.05*
Participant2-Group3	50.12 ± 20.45	37.20 ± 17.46	<0.05*
Participant3-Group3	40.57 ± 20.51	37.20 ± 17.46	0.315
Participant4-Group3	46.44 ± 20.84	37.20 ± 17.46	<0.05*
Participant5-Group3	41.50 ± 19.50	37.20 ± 17.46	0.282

*Significant at p <0.05

TSCDIFF

	Individual ($\bar{\square} \pm \square$) n=54	Group ($\bar{\square} \pm \square$) n=54	p
Participant1-Group3	36.23 ± 13.03	37.20 ± 17.46	0.069

Participant2-Group3	53.31 ± 20.20	37.20 ± 17.46	<0.05*
Participant3-Group3	22.11 ± 11.51	37.20 ± 17.46	<0.05*
Participant4-Group3	42.95 ± 15.44	37.20 ± 17.46	<0.05*
Participant5-Group3	33.27 ± 15.07	37.20 ± 17.46	0.187

*Significant at p <0.05

MSCDIFF

	Individual (□ ± □) n=54	Group (□ ± □) n=54	p
Participant1-Group4	45.37 ± 16.81	41.30 ± 16.93	0.202
Participant2-Group4	48.61 ± 25.10	41.30 ± 16.93	0.060
Participant3-Group4	50.77 ± 23.15	41.30 ± 16.93	<0.05*
Participant4-Group4	46.36 ± 18.54	41.30 ± 16.93	0.188
Participant5-Group4	34.88 ± 18.75	41.30 ± 16.93	0.068

*Significant at p <0.05

TSCDIFF

	Individual (□ ± □) n=54	Group (□ ± □) n=54	p
Participant1-Group4	37.29 ± 20.16	41.30 ± 16.93	0.269
Participant2-Group4	27.90 ± 16.68	41.30 ± 16.93	<0.05*
Participant3-Group4	33.16 ± 13.38	41.30 ± 16.93	<0.05*
Participant4-Group4	39.18 ± 11.01	41.30 ± 16.93	0.406
Participant5-Group4	31.96 ± 13.13	41.30 ± 16.93	<0.05*

*Significant at p <0.05

MSCDIFF

	Individual (□̄ ± □) n=54	Group (□̄ ± □) n=54	p
Participant1-Group5	39.87 ± 21.37	45.88 ± 17.89	0.134
Participant2-Group5	47.88 ± 25.69	45.88 ± 17.89	0.659
Participant3-Group5	41.96 ± 18.16	45.88 ± 17.89	0.288
Participant4-Group5	53.19 ± 24.75	45.88 ± 17.89	0.094
Participant5-Group5	37.17 ± 18.29	45.88 ± 17.89	<0.05*

*Significant at p <0.05

TSCDIFF

	Individual (□̄ ± □) n=54	Group (□̄ ± □) n=54	p
Participant1-Group5	38.70 ± 15.09	45.88 ± 17.89	<0.05*
Participant2-Group5	31.27 ± 17.53	45.88 ± 17.89	<0.05*
Participant3-Group5	27.43 ± 10.98	45.88 ± 17.89	<0.05*
Participant4-Group5	58.85 ± 10.55	45.88 ± 17.89	<0.05*
Participant5-Group5	31.91 ± 17.33	45.88 ± 17.89	<0.05*

*Significant at p <0.05

MSCDIFF

	Individual (□̄ ± □) n=54	Group (□̄ ± □) n=54	p
Participant1-Group6	46.89 ± 16.80	33.53 ± 13.42	<0.05*
Participant2-Group6	45.72 ± 23.53	33.53 ± 13.42	<0.05*
Participant3-Group6	45.07 ± 15.55	33.53 ± 13.42	<0.05*
Participant4-Group6	46.89 ± 16.80	33.53 ± 13.42	<0.05*
Participant5-Group6	43.45 ± 19.12	33.53 ± 13.42	<0.05*

*Significant at p <0.05

TSCDIFF

	Individual (□̄ ± □) n=54	Group (□̄ ± □) n=54	p
Participant1-Group6	27.90 ± 16.68	33.53 ± 13.42	0.089
Participant2-Group6	30.26 ± 13.69	33.53 ± 13.42	0.211
Participant3-Group6	35.64 ± 12.08	33.53 ± 13.42	0.396
Participant4-Group6	43.09 ± 8.58	33.53 ± 13.42	<0.05*
Participant5-Group6	28.98 ± 9.72	33.53 ± 13.42	<0.05*

*Significant at p <0.05

MHITTIME

	Individual (□̄ ± □) n=54	Group (□̄ ± □) n=54	p
Participant1-Group1	1036 ± 182	1476 ± 482	<0.05*
Participant2-Group1	958 ± 179	1476 ± 482	<0.05*
Participant3-Group1	1201 ± 228	1476 ± 482	<0.05*
Participant4-Group1	1031 ± 184	1476 ± 482	<0.05*
Participant5-Group1	1110 ± 209	1476 ± 482	<0.05*

*Significant at p <0.05

THITTIME

	Individual (□̄ ± □) n=54	Group (□̄ ± □) n=54	p
Participant1-Group1	1809 ± 640	1476 ± 482	<0.05*
Participant2-Group1	1893 ± 605	1476 ± 482	<0.05*
Participant3-Group1	1579 ± 545	1476 ± 482	0.245
Participant4-Group1	1622 ± 499	1476 ± 482	0.114
Participant5-Group1	1891 ± 800	1476 ± 482	<0.05*

*Significant at p <0.05

MHITTIME

	Individual (□ ± □) n=54	Group (□ ± □) n=54	p
Participant1-Group2	1051 ± 193	1090 ± 354	0.659
Participant2-Group2	1071 ± 249	1090 ± 354	<0.05*
Participant3-Group2	1139 ± 229	1090 ± 354	0.633
Participant4-Group2	1093 ± 207	1090 ± 354	<0.05*
Participant5-Group2	1086 ± 187	1090 ± 354	<0.05*

*Significant at p <0.05

THITTIME

	Individual (□ ± □) n=54	Group (□ ± □) n=54	p
Participant1-Group2	1716 ± 674	1090 ± 354	<0.05*
Participant2-Group2	1990 ± 894	1090 ± 354	0.096
Participant3-Group2	1755 ± 633	1090 ± 354	<0.05*
Participant4-Group2	1838 ± 746	1090 ± 354	0.140
Participant5-Group2	1867 ± 704	1090 ± 354	<0.05*

*Significant at p <0.05

MHITTIME

	Individual (□ ± □) n=54	Group (□ ± □) n=54	p
Participant1-Group3	1037 ± 160	1267 ± 533	0.53
Participant2-Group3	975 ± 301	1267 ± 533	<0.05*
Participant3-Group3	1029 ± 219	1267 ± 533	0.067
Participant4-Group3	961 ± 162	1267 ± 533	<0.05*
Participant5-Group3	1213 ± 206	1267 ± 533	0.335

*Significant at p <0.05

THITTIME

	Individual (□ ± □) n=54	Group (□ ± □) n=54	p
Participant1-Group3	1655 ± 662	1267 ± 533	<0.05*
Participant2-Group3	1730 ± 535	1267 ± 533	<0.05*
Participant3-Group3	1918 ± 647	1267 ± 533	<0.05*
Participant4-Group3	1735 ± 725	1267 ± 533	<0.05*
Participant5-Group3	2013 ± 880	1267 ± 533	<0.05*

*Significant at p <0.05

MHITTIME

	Individual (□ ± □) n=54	Group (□ ± □) n=54	p
Participant1-Group4	1045 ± 178	1348 ± 558	<0.05*
Participant2-Group4	1078 ± 227	1348 ± 558	<0.05*
Participant3-Group4	1048 ± 181	1348 ± 558	<0.05*
Participant4-Group4	1165 ± 191	1348 ± 558	0.400
Participant5-Group4	1074 ± 212	1348 ± 558	<0.05*

*Significant at p <0.05

THITTIME

	Individual (□ ± □) n=54	Group (□ ± □) n=54	p
Participant1-Group4	1695 ± 611	1348 ± 558	<0.05*
Participant2-Group4	1530 ± 534	1348 ± 558	<0.05*
Participant3-Group4	2117 ± 757	1348 ± 558	<0.05*
Participant4-Group4	1955 ± 660	1348 ± 558	<0.05*
Participant5-Group4	1775 ± 703	1348 ± 558	<0.05*

*Significant at p <0.05

MHITTIME

	Individual (□̄ ± □) n=54	Group (□̄ ± □) n=54	p
Participant1-Group5	1052 ± 195	1251 ± 321	<0.05*
Participant2-Group5	1030 ± 310	1251 ± 321	<0.05*
Participant3-Group5	1062 ± 187	1251 ± 321	<0.05*
Participant4-Group5	1051 ± 172	1251 ± 321	<0.05*
Participant5-Group5	1199 ± 593	1251 ± 321	0.092

*Significant at p <0.05

THITTIME

	Individual (□̄ ± □) n=54	Group (□̄ ± □) n=54	p
Participant1-Group5	1098 ± 757	1251 ± 321	<0.05*
Participant2-Group5	1054 ± 555	1251 ± 321	<0.05*
Participant3-Group5	1925 ± 655	1251 ± 321	<0.05*
Participant4-Group5	2031 ± 660	1251 ± 321	<0.05*
Participant5-Group5	2033 ± 703	1251 ± 321	<0.05*

*Significant at p <0.05

MHITTIME

	Individual (□̄ ± □) n=54	Group (□̄ ± □) n=54	p
Participant1-Group6	1176 ± 175	1348 ± 672	0.604
Participant2-Group6	1104 ± 187	1348 ± 672	<0.05*
Participant3-Group6	1143 ± 179	1348 ± 672	0.312
Participant4-Group6	1176 ± 175	1348 ± 672	0.604
Participant5-Group6	1155 ± 217	1348 ± 672	0.151

*Significant at p <0.05

THITTIME

	Individual (□ ± □) n=54	Group (□ ± □) n=54	p
Participant1-Group6	1530 ± 534	1348 ± 672	<0.05*
Participant2-Group6	2029 ± 930	1348 ± 672	<0.05*
Participant3-Group6	2050 ± 734	1348 ± 672	<0.05*
Participant4-Group6	2052 ± 739	1348 ± 672	<0.05*
Participant5-Group6	1818 ± 660	1348 ± 672	<0.05*

*Significant at p <0.05

MEC

	% of Error Count (Individual)			% of Error Count (Group)			p
Error Count	0	1	2	0	1	2	
Participant1-Group1	98.1%	1.9%	0.0%	92.6%	3.7%	3.7%	0.960
Participant2-Group1	94.4%	5.6%	0.0%	92.6%	3.7%	3.7%	0.881
Participant3-Group1	87.0%	13.0%	0.0%	92.6%	3.7%	3.7%	0.250
Participant4-Group1	96.3%	3.7%	0.0%	92.6%	3.7%	3.7%	0.920
Participant5-Group1	98.1%	1.9%	0.0%	92.6%	3.7%	3.7%	0.960

*Significant at p <0.05

TEC

	% of Error Count (Individual)			% of Error Count (Group)			p
Error Count	0	1	2	0	1	2	
Participant1-Group1	96.3%	3.1%	0.0%	92.6%	3.7%	3.7%	0.920
Participant2-Group1	100.0%	0.0%	0.0%	92.6%	3.7%	3.7%	-
Participant3-Group1	87.0%	13.0%	0.0%	92.6%	3.7%	3.7%	0.725
Participant4-Group1	100.0%	0.0%	0.0%	92.6%	3.7%	3.7%	-
Participant5-Group1	100.0%	0.0%	0.0%	92.6%	3.7%	3.7%	-

*Significant at p <0.05

MEC

	% of Error Count (Individual)	% of Error Count (Group)	p

Error Count	0	1	2	0	1	2	
Participant1-Group2	94.4%	5.6%	0.0%	75.9%	24.1%	0.0%	0.430
Participant2-Group2	85.2%	14.8%	0.0%	75.9%	24.1%	0.0%	0.373
Participant3-Group2	96.3%	1.9%	1.9%	75.9%	24.1%	0.0%	0.174
Participant4-Group2	94.4%	5.6%	0.0%	75.9%	24.1%	0.0%	0.430
Participant5-Group2	98.1%	1.9%	0.0%	75.9%	24.1%	0.0%	0.759

*Significant at p <0.05

TEC

	% of Error Count (Individual)			% of Error Count (Group)			p
Error Count	0	1	2	0	1	2	
Participant1-Group2	100.0%	0.0%	0.0%	75.9%	24.1%	0.0%	-
Participant2-Group2	85.2%	14.8%	0.0%	75.9%	24.1%	0.0%	0.290
Participant3-Group2	98.1%	1.9%	0.0%	75.9%	24.1%	0.0%	0.241
Participant4-Group2	77.8%	22.2%	0.0%	75.9%	24.1%	0.0%	0.602
Participant5-Group2	96.3%	3.7%	0.0%	75.9%	24.1%	0.0%	0.427

*Significant at p <0.05

MEC

	% of Error Count (Individual)			% of Error Count (Group)			p
Error Count	0	1	2	0	1	2	
Participant1-Group3	94.4%	5.6%	0.0%	100.0%	0.0%	0.0%	-
Participant2-Group3	94.4%	5.6%	0.0%	100.0%	0.0%	0.0%	-
Participant3-Group3	94.4%	3.7%	1.9%	100.0%	0.0%	0.0%	-
Participant4-Group3	94.4%	5.6%	0.0%	100.0%	0.0%	0.0%	-
Participant5-Group3	98.1%	1.9%	0.0%	100.0%	0.0%	0.0%	-

*Significant at $p < 0.05$

TEC

	% of Error Count (Individual)			% of Error Count (Group)			p
Error Count	0	1	2	0	1	2	
Participant1-Group3	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	-
Participant2-Group3	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	-
Participant3-Group3	98.1%	1.9%	0.0%	100.0%	0.0%	0.0%	-
Participant4-Group3	98.1%	1.9%	0.0%	100.0%	0.0%	0.0%	-
Participant5-Group3	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	-

*Significant at $p < 0.05$

MEC

	% of Error Count (Individual)			% of Error Count (Group)			p
Error Count	0	1	2	0	1	2	
Participant1-Group4	96.3%	1.9%	1.9%	100.0%	0.0%	0.0%	-
Participant2-Group4	96.3%	3.7%	0.0%	100.0%	0.0%	0.0%	-
Participant3-Group4	92.6%	7.4%	0.0%	100.0%	0.0%	0.0%	-
Participant4-Group4	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	-
Participant5-Group4	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	-

*Significant at p <0.05

TEC

	% of Error Count (Individual)			% of Error Count (Group)			p
Error Count	0	1	2	0	1	2	
Participant1-Group4	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	-
Participant2-Group4	98.1%	1.9%	0.0%	100.0%	0.0%	0.0%	-
Participant3-Group4	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	-
Participant4-Group4	98.1%	1.9%	0.0%	100.0%	0.0%	0.0%	-
Participant5-Group4	96.3%	3.7%	0.0%	100.0%	0.0%	0.0%	-

*Significant at p <0.05

MEC

	% of Error Count (Individual)				% of Error Count (Group)			p
Error Count	0	1	2	3	0	1	2	
Participant1-Group5	98.1%	1.9%	0.0%	0.0%	75.9%	24.1%	0.0%	0.759
Participant2-Group5	77.8%	18.5%	1.9%	1.9%	75.9%	24.1%	0.0%	0.843
Participant3-Group5	98.1%	1.9%	0.0%	0.0%	75.9%	24.1%	0.0%	0.759
Participant4-Group5	92.6%	7.4%	0.0%	0.0%	75.9%	24.1%	0.0%	0.680
Participant5-Group5	98.1%	1.9%	0.0%	0.0%	75.9%	24.1%	0.0%	0.759

*Significant at p <0.05

TEC

	% of Error Count (Individual)			% of Error Count (Group)			p
Error Count	0	1	2	0	1	2	
Participant1-Group5	98.1%	1.9%	0.0%	75.9%	24.1%	0.0%	0.759
Participant2-Group5	40.7%	57.4%	1.9%	75.9%	24.1%	0.0%	0.562
Participant3-Group5	98.1%	1.9%	0.0%	75.9%	24.1%	0.0%	0.759
Participant4-Group5	100.0%	0.0%	0.0%	75.9%	24.1%	0.0%	-
Participant5-Group5	100.0%	0.0%	0.0%	75.9%	24.1%	0.0%	-

*Significant at p <0.05

MEC

	% of Error Count (Individual)			% of Error Count (Group)			p
Error Count	0	1	2	0	1	2	
Participant1-Group6	98.1%	1.9%	0.0%	100.0%	0.0%	0.0%	-
Participant2-Group6	98..%	1.9%	0.0%	100.0%	0.0%	0.0%	-
Participant3-Group6	98.1%	1.9%	0.0%	100.0%	0.0%	0.0%	-
Participant4-Group6	98.1%	1.9%	0.0%	100.0%	0.0%	0.0%	-
Participant5-Group6	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	-

*Significant at $p < 0.05$

TEC

	% of Error Count (Individual)			% of Error Count (Group)			p
Error Count	0	1	2	0	1	2	
Participant1-Group6	98.1%	1.9%	0.0%	100.0%	0.0%	0.0%	-
Participant2-Group6	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	-
Participant3-Group6	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	-
Participant4-Group6	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	-
Participant5-Group6	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	-

*Significant at $p < 0.05$

APPENDIX I

TEST 3 STATISTICAL ANALYSIS TABLES

One-Sample Kolmogorov-Smirnov Test

		TH	MM	MR	MZ	DM	DR	DZ	THGR	MMGR	MRGR	MZGR	DMGR	DRGR	DZGR
N		30	30	30	30	30	30	30	6	6	6	6	6	6	6
Normal Parameters[a,b]	Mean	7,4000	,6667	,9000	1,2667	12,6000	10,4667	8,4667	26,1667	,1667	1,6667	4,0000	99,0000	49,5000	29,6667
	Std. Deviation	2,48582	1,32179	1,47040	,90719	7,55029	4,43912	5,15774	4,35507	,40825	1,50555	1,09545	36,76955	7,66159	15,68014
Most Extreme Differences	Absolute	,171	,393	,273	,416	,151	,109	,169	,257	,492	,312	,333	,471	,222	,308
	Positive	,171	,393	,273	,416	,151	,109	,169	,257	,492	,199	,333	,471	,222	,308
	Negative	-,087	-,307	-,270	-,318	-,094	-,089	-,144	-,143	-,342	-,312	-,181	-,322	-,164	-,248
Kolmogorov-Smirnov Z		,938	2,153	1,495	2,276	,825	,594	,928	,631	1,205	,764	,816	1,155	,543	,754
Asymp. Sig. (2-tailed)		,342	,000	,023	,000	,504	,872	,356	,821	,110	,603	,518	,139	,930	,621

a. Test distribution is Normal.

b. Calculated from data.

Descriptives

	Individual			Statistic	Std. Error
Rotate	Menu	Mean		122,5000	13,26450
		95% Confidence Interval for Mean	Lower Bound	93,3050	
			Upper Bound	151,6950	
		5% Trimmed Mean		117,7778	
		Median		110,0000	
		Variance		2111,364	
		Std. Deviation		45,94958	
		Minimum		80,00	
		Maximum		250,00	
		Range		170,00	
		Interquartile Range		37,50	
		Skewness		2,189	,637
		Kurtosis		5,599	1,232
	Direct	Mean		131,2978	3,30040
		95% Confidence Interval for Mean	Lower Bound	124,7483	
			Upper Bound	137,8474	
		5% Trimmed Mean		130,5916	
		Median		129,0667	
		Variance		1078,372	
		Std. Deviation		32,83858	
		Minimum		42,59	
		Maximum		250,51	
		Range		207,92	
		Interquartile Range		48,41	
		Skewness		,400	,243
		Kurtosis		,877	,481

Descriptives

	Group			Statistic	Std. Error
Rotate	Direct	Mean		139,7929	6,39098
		95% Confidence Interval for Mean	Lower Bound	126,7584	
			Upper Bound	152,8274	
		5% Trimmed Mean		137,9473	
		Median		134,0099	
		Variance		1307,030	
		Std. Deviation		36,15287	
		Minimum		90,30	
		Maximum		231,65	
		Range		141,35	
		Interquartile Range		52,39	
		Skewness		,670	,414
		Kurtosis		,031	,809

Descriptives

	Individual			Statistic	Std. Error
Zoom	Menu	Mean		,1309	,00818
		95% Confidence Interval for Mean	Lower Bound	,1142	
			Upper Bound	,1475	
		5% Trimmed Mean		,1299	
		Median		,1500	
		Variance		,002	
		Std. Deviation		,04770	
		Minimum		,05	
		Maximum		,25	
		Range		,20	
		Interquartile Range		,05	
		Skewness		-,469	,403
		Kurtosis		,420	,788
	Direct	Mean		,0740	,00401
		95% Confidence Interval for Mean	Lower Bound	,0660	
			Upper Bound	,0820	
		5% Trimmed Mean		,0737	
		Median		,0770	
		Variance		,001	
		Std. Deviation		,03568	
		Minimum		,00	
		Maximum		,20	
		Range		,20	
		Interquartile Range		,05	
		Skewness		,265	,271
		Kurtosis		,661	,535

Group Statistics

	Individual	N	Mean	Std. Deviation	Std. Error Mean
Zoom	Menu	34	,1309	,04770	,00818
	Direct	79	,0740	,03568	,00401

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Zoom	Equal variances assumed	3,201	,076	6,999	111	,000	,05690	,00813	,04079	,07301
	Equal variances not assumed			6,244	49,592	,000	,05690	,00911	,03859	,07520

Descriptives

	Group			Statistic	Std. Error
Zoom	Menu	Mean		,1556	,00556
		95% Confidence Interval for Mean	Lower Bound	,1427	
			Upper Bound	,1684	
		5% Trimmed Mean		,1534	
		Median		,1500	
		Variance		,000	
		Std. Deviation		,01667	
		Minimum		,15	
		Maximum		,20	
		Range		,05	
		Interquartile Range		,00	
		Skewness		3,000	,717
		Kurtosis		9,000	1,400
	Direct	Mean		,0815	,00789
		95% Confidence Interval for Mean	Lower Bound	,0650	
			Upper Bound	,0980	
		5% Trimmed Mean		,0815	
		Median		,0736	
		Variance		,001	
		Std. Deviation		,03530	
		Minimum		,00	
		Maximum		,16	
		Range		,16	
		Interquartile Range		,04	
		Skewness		,184	,512
		Kurtosis		,676	,992

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Zoom	Menu	9	,1556	,01667	,00556
	Direct	20	,0815	,03530	,00789

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Zoom	Equal variances assumed	4,331	,047	5,955	27	,000	,07403	,01243	,04852	,09954
	Equal variances not assumed			7,670	26,843	,000	,07403	,00965	,05422	,09384

CURRICULUM VITAE

Tacettin Sercan Pekin

UPDATE

29.05.2017

DEGREES

B.S. in Computer Science, 2007
B.A. in Business Administration, 2013
M.S. in Computer Science, 2010
Ph.D. (Candidate) in Information Systems, 2017

PERSONAL INFORMATION

Mobile Phone : 009 0532 200 28 96
e-mail Address : sepekin@gmail.com
Address : Cigdem Mh. 1577. Sk. Gazi Ap. No:2/7 Cankaya Ankara Turkey

CONTACT INFORMATION

Marital Status : Married
Nationality : Turkish
Date and Place of Birth : July 02, 1985 - Ankara/Turkey
Mandatory Military Service : Completed

WORK EXPERIENCES

March 2017 – Present

Scientific Programs Expert at TÜBİTAK, worked as expert for monitoring and evaluating of recent research and development projects of individuals, companies and universities. Research area of the projects are identified and related academician is assigned to track the project. Summary and evaluation of the process is made and supporting of the firm is decided.

July 2013 – March 2017

Technical Leader at Simsoft Bilgi Sistemleri, worked on electronic warfare simulations and training of military staff. Created a serious game simulation for a foreign country's army. Military officer candidates used the system for training and practice approaches. Application was written with C# language and Unity Game Engine. Leaded a team of 3 people and actively participated coding on all aspects. Also created a virtual maintenance system with a team which will be used for unmanned aircrafts. System is used by Turkish Army.

April 2011 – March 2017

Founder and Managing Director at Pekin Software, developed a system which is supported by the Ministry of Science, Industry and Technology and completed in June 2012 with a budget of 100.000 TL. Leaded whole project which consists of 4 members. Application was written with JSP, JAVA, MS SQL, Android and works as a server-client application for food ordering in restaurants and food courts of shopping malls.

Founder and Managing Director at TeshisPek Agricultural Software, developed a system which is supported by the Ministry of Science, Industry and Technology and completed in June 2012 with a budget of 86.000 TL. Leaded whole project which consists of 5 members. Application was written with JSP, JAVA, MS SQL and works as a web based application for diagnosis and treatment of agricultural diseases.

June 2012 – July 2013

Team Leader at BSB Bilisim, worked on e-learning and education systems developed by the Turkish Government to enhance active learning mechanisms. Leaded a team of 4 people for web-based, mobile-based and server-client based applications. Actively participated coding for server-side programming and mobile client-side programming.

December 2010 – June 2012

Full-time Software Engineer at SMSNet/Globsis, worked on mobile advertising, ad serving and internet technologies. Developed a system for mobile advertising and ad serving. Worked with JAVA platform in multi-user working environment for multi-threaded applications. Real time high rate internet traffic is controlled with the written applications.

February 2008 – December 2010

Part-time Software Engineer and Researcher at 3DPHONE Project, worked on human computer interaction on mobile devices and input technologies. Developed a 2D input system for mobile 3D devices using camera-based finger tracking techniques. Developed touch screen based gesture library.

September 2007 – June 2010

Teaching Assistant for Algorithms and Programming, Object-Oriented Software Engineering, Introduction to Computing for Social Sciences courses at Bilkent University, Department of Computer Engineering. Research Assistant in Human Computer Interaction and Mobile Computing, led by Asst. Prof. Tolga K. Capin

September 2007 – September 2008

Part-time Software Engineer at IC Ictas Insaat, Human Resources Department, worked on developing an Electronic Human Resources Management System. Developed a complete human management and documentation program.

September 2006 – September 2007

Part-time Software Engineer at YDA Insaat, Human Resources Department, worked on developing an Electronic Human Resources Management System. Developed a complete human management and documentation program.

SUMMER INTERNSHIP

June 2006 – July 2006

System Admin and Software Consultant at Sybase Turkey, worked as System Admin and Software Consultant for the partner companies and database systems.

June 2005 – July 2005

Microsoft Summer School Student Participant at Microsoft Turkey, attended a four week course on operating systems, database systems, object oriented software engineering and high level project management topics. Detailed software knowledge is given on Microsoft Family.

EDUCATION

September 2011-Present:

Middle East Technical University, Turkey, Informatics Institute, Information Systems, **Ph.D.**

Cumulative GPA 3.83/4.0

Courses Taken During Graduate Education: Data Base Concepts and Applications, Game Development Pipeline, Introduction to Software Engineering, Introduction to Information Systems, Information Systems Project, Computer Networking for Information Systems, Object-Oriented Analysis and Design, Software Design Patterns, Mobile Business

Thesis Topic and Advisor: Efficient Interaction on Multi-Touch Large Screens to Enhance Collaboration in Serious Games – Assoc. Prof. Veysi Isler

September 2007-August 2010:

Bilkent University, Turkey, Graduate School of Engineering and Science, Computer Engineering (Graphical User Interfaces and Human Computer Interaction), **M.S.**

Cumulative GPA 3.77/4.0

Courses Taken During Graduate Education: Mobile and Ubiquitous Graphics, Advanced Topics in Computer Graphics, Computer Animation, Application of Computer Graphics, Virtual Reality, Natural Language Processing, Advances in Switching Networks I-II

Thesis Topic and Advisor: Camera-Based 3D Interaction for Handheld Devices – Asst. Prof. Tolga K. Capin

September 2007-June 2013:

Anadolu University, Turkey, Faculty of Business Administration, Business Administration, **B.A.**

Cumulative GPA 2.62/4.0

September 2003-May 2007:

Bilkent University, Turkey, Department of Computer Engineering, Computer Engineering and Information Sciences, **B.S.**

Cumulative GPA 3.13/4.0

September 1996-June 2003:

Sungurlu Haydar Oztas Anatolian High School, Turkey, Natural Science and Mathematics Studies

Cumulative GPA: 5.00/5.00

PUBLICATIONS

Conference Papers

Pekin, T. S., İşler, V., & Günsel, B. (2015). Usability Comparison of Large Touchscreen Systems versus Desktop-Size and Mobile-Size Screen Systems. Deniz Bilimleri ve Mühendisliği Dergisi, 11(3).

DOCTOR OF PHILOSOPHY STUDIES

September 2011-Present

Middle East Technical University, Informatics Institute, Information Systems, On-The-Fly Tuning Online Game Play for Pulling Gamers to Flow State Based on Data Mining. Supervised by Assoc. Prof. Veysi Isler.

MASTER of SCIENCE STUDIES

September 2007-August 2010

Bilkent University, Computer Engineering, Computer Graphics, Human Computer Interaction, 3D User Interfaces, Alternative 3D Input Techniques for Mobile Devices. Created a 3D interaction method for mobile devices based on finger tracking from camera based input. Supervised by Asst. Prof. Tolga K. Capin.

SENIOR DESIGN PROJECT

September 2006 – May 2007

Natural Language Processing; Entity Recognition System; Java: Given a text as input, file or HTML address, system automatically detects certain type of entities like name, date, etc. A predefined database is used to detect known entities. Rest of the entities is identified according to the defined rules. Output is given as graphical output and/or in XML format.

COMPUTER SKILLS

1. • Advanced-known Languages: Java, C#, JSP, Android, C++, QT, OpenGL, SQL, HTML.
2. • Intermediate-known Languages: C, OpenGL ES, M3G, PHP, Verilog, MIPS Assembly, Perl.
3. • Skills: OOAD, UML1.1-2.0, Software Engineering Principles, Mobile Development, Basic Network Topologies, Web development, Principles of User Interfaces, Graphics Design.
4. • Game Engines: Unity Game Engine.

5. • Operating Systems: Windows 9x, 2000, XP, Vista, 7, Windows Server 2003-2008, Linux.
6. • Tools and Platforms: IntelliJ IDEA, Ms Visual Studio, Ms Visual C++, Eclipse, Borland Together with Eclipse, Sun ONE Web Server, Sun Java Wireless Toolkit, Ms Office.
7. • Certificates: Microsoft Summer School Participation, MEB Computer Education Certificates.
8. • Field of Interest: Human-computer interaction, user interfaces, computer graphics, computer game development, OO software engineering, web-based programming, ad serving and e-commerce.

KNOWN LANGUAGES

9. • Turkish (native)
10. • Fluent English
11. • Basic German

PERSONAL PROJECTS

April 2011

Developed a system which is supported by the Ministry of Science, Industry and Technology and completed in June 2012 with a budget of 100.000 TL. Leaded whole project which consists of 4 members. Application was written with JSP, JAVA, MS SQL, Android and works as a server-client application for food ordering in restaurants and food courts of shopping malls.

April 2011

Developed a system which is supported by the Ministry of Science, Industry and Technology and completed in June 2012 with a budget of 86.000 TL. Leaded whole project which consists of 5 members. Application was written with JSP, JAVA, MS SQL and works as a web based application for diagnosis and treatment of agricultural diseases.

Spring 2010

Internet Supported Media Player Application; Online Desktop Player (ODP); C++, QT.
A music player application enabling users to store their media files on line and listen to them from anywhere with internet connection. Graphical user interface support is at high level with QT to enable cross platform support. Both executable from installed locations or from web surfing tools.

Spring 2006

Movie List Database Program; Movie Data; Java (txt based database program).
A program that a person can track information about the movies that he/she owns.
Spring 2010.

HONORS AND AWARDS

12. • 2003-2007: In Dean's List, Bilkent University (5 times in High Honors and Honors out of a total of 8 semesters).
13. • 2003: Ranked 1st in Sungurlu/Corum among 1.5 million examinees in University Entrance Examination (ÖSS).
14. • 2003: Ranked 1st at graduation from high school.