USER SATISFACTION RELATED DESIGN RECOMMENDATIONS FOR NON-KEYBOARD INPUT DEVICES IN MILITARY

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ABSTRACT

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Information on user satisfaction is a significant input for product design process. In order to measure user satisfaction related with the consumer products, many studies have been carried out by researchers. However, military products were not taken into account in most of these studies. This study aims to evaluate *mouse, touchpad, hula pointer and trackball* which are non-keyboard input devices (NKIDs) integrated in operator consoles as working areas in military in terms of user satisfaction. For this sake, a field study was conducted with 21 operators from three different Turkish Military Forces; namely, Land, Air and Navy. When the data were evaluated, mouse was found as the most satisfactory device by the participants. Operators were also asked to rate the devices based on suitability to their platforms on which they work. Although mouse was preferred as the most satisfactory device; only Land Forces preferred it as the most suitable one for their platforms. Regarding their usage in the platforms, trackball was preferred by Navy Forces, whereas the touchpad preferred by the Air Forces as the most suitable ones. Consequently, it is found that different platforms require different NKIDs. Furthermore, design recommendations in relation with the selection and integration of NKIDs were generated based on the participant operators' preferences.

Keywords: User Satisfaction, NKIDs, Military Input Devices, Usability, Satisfaction Measurement

ÖZ

ASKERİYEDE KULLANILAN KLAVYE HARİCİ GİRİŞ AYGITLARI İÇİN KULLANICI MEMNUNİYETİNE İLİŞKİN TASARIM ÖNERİLERİ

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Kullanıcı memnuniyeti bilgisi ürün tasarımı sürecini etkileyen önemli bir girdidir. İlgili literatür incelendiğinde bu alanda birçok çalışma yapıldığı ancak bu çalışmaların savunma sanayinde kullanılan ürünler için yetersiz kaldığı görülmüştür. Tezin amacı savunma sanayinde operatörlerin çalışma alanı olarak tasarlanan konsollarda kullanılan klavye harici giriş aygıtlarının *-fare, touchpad, hula pointer ve iz topunun-* kullanımını kullanıcı memnuniyeti açısından değerlendirmektir. Bu bağlamda Kara, Deniz ve Hava Kuvvetlerinden yedişer olmak üzere toplam 21 operatörle anket ve odak grup görüşmelerinden oluşan bir alan çalışması yapılmıştır. Elde edilen data analiz edildiğinde, fare cihazının performans, tasarım, rahatlık ve çalışma şekli ölçütlerine göre diğer cihazlardan daha yeterli görüldüğü ortaya çıkmıştır. Ayrıca çalışmada cihazların platformlara uygunluğu da sorgulanmıştır. Veriler kategorize edildiğinde Kara Kuvvetleri yine fare cihazını uygun görürken; Deniz Kuvvetleri iztopunu ve Hava Kuvvetleri ise touchpadi kendi platformlarına daha uygun bulmuşlardır. Sonuç olarak askeriyede farklı platformların farklı klavye harici giriş aygıtlarına ihtiyaçları olduğu tespit edilmiştir. Ayrıca, katılımcı operatörlerin tercihleri göz önüne alınarak klavye harici giriş aygıtlarının seçimine ve entegrasyonuna dair tasarım önerileri oluşturulmuştur.

Anahtar kelimeler: Kullanıcı Memnuniyeti, Klavye Harici Giriş Aygıtları, Askeri Giriş Aygıtları, Kullanılabilirlik, Memnuniyet Ölçümü

Dedicated to the Memories of
Hasan CANTÜRK and Mustafa ÜRÜN

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CHAPTER 1

INTRODUCTION

1.1 Background

In 1960s, an engineer and his colleagues invented a device called '*mouse*' from a wooden box while they were working in an electronics company. They did not declare this invention and did not receive any royalties from it. Their intention was to develop a simple alternative of light pen and they probably did not predict that this device would become very popular and be widely used (Jessen et al, 2010).

Mouse is just one of the input devices for computing systems that include input and output devices to establish connections between users and computers. Light pen, mouse, keyboard, joystick, trackball are some of the examples for input devices and monitor and printer are for output devices. Input devices are divided into two groups, namely keyboards and non-keyboards input devices (NKIDs) which are called as pointers as well. The wide varieties of non-keyboard input devices have caused a challenge for designers, engineers etc. to choose a suitable one for computing systems. Therefore, researchers have required making empirical evaluations to compare these devices objectively. Objective evaluations are related to device performance, such as task completion time, accuracy, ease of operation (Accot & Zhai, 1999). However, today's evaluation of NKIDs has gone beyond objective measurements. Subjective evaluations, which measure preferences and satisfaction of the users in relation to NKIDs, have begun to be taken into consideration (Woods et al, 2003).

Satisfaction is one of the complex terms when user-product relationship is considered. Therefore, it has been defined in many different ways by different researchers. In usability engineering discipline, early studies identified the satisfaction as “the system should be pleasant to use, so that users are subjectively satisfied when using it” (Nielsen, 1993 pp 26). Similarly, ISO 9241-11 defined satisfaction as “*freedom from discomfort and positive attitudes to the use of the product*” (1998, pp 2). First, marketing discipline then, usability engineering discipline began to be interested in satisfaction. Marketing literature has investigated satisfaction as a consumer activity and usability engineering literature has focused on satisfaction as a subjective part of product’s usage (Altas, 2006). Most importantly for this thesis study, Human Computer Interaction (HCI) discipline has been interested in satisfaction (Dillon, 2001). HCI researchers defined satisfaction as subjective part of usability and recent studies show that HCI literature began to focus on subjective part of usability more than performance-enhancing models (Lindgaard & Whitfield, 2004). So, they used questionnaire technique, such as Questionnaire for User Interaction Satisfaction (QUIS) (Chin et al., 1988), Software Usability Measurement Inventory (SUMI) (Kirakowski and Corbett, 1993), Post-Study System Usability Questionnaire (PSSUQ) (Lewis, 1995), System Usability Scale (SUS) (Brooke, 1996) and Purdue Usability Testing Questionnaire (PUTQ) (Lin et al., 1997) as a tool to measure satisfaction. The detailed information about these questionnaires will be given in the following chapters.

As mentioned before, early studies on user satisfaction have been generated by marketing and usability engineering disciplines. Then, product design discipline began to be interested in user satisfaction. In fact, this interest has developed in parallel with the technological developments, and, researchers have focused more on consumer products, such as mobile phones. But, since consumer electronic products have both software and hardware features and existing questionnaires mainly focus on software products, researchers developed new questionnaires, such as the Mobile Phone Usability Questionnaire (MPUQ) (Ryu, 2005) and Consumer Product Questionnaire (CPQ) (McNamara, 2006). With these measurement tools, designers try to understand the relationship between satisfaction and performance of the users. In this context, researchers claim that there is a positive correlation between user satisfaction and user performance (Nielsen & Levy, 1994).

Issues of satisfaction and performance are even more serious for the defense industry. User performance is a crucial factor for the success in a military mission and as mentioned above, it can be said that user performance and user satisfaction are influenced by each other. However, the studies and tools used for evaluating user satisfaction in the literature are inadequate for military products. Moreover, in the defense industry, designers are expected to adhere to military standards and these standards have general features and dimensions for non-keyboard input devices. While designing military console, a workspace consisting of a screen, a keyboard, a touchscreen, a knob and a pointing device, designers need to consider some design criteria to select the most suitable NKIDs. Therefore, it is necessary to analyze user satisfaction in the military and generate design recommendations for the selection and integration of NKIDs.

1.2 Aim of the Study

As mentioned before, the selection of NKIDs is crucial for performance of the operators in a military console design. However, MIL-STD 1472G, which is a military standard including design criteria, principles, and practices concerning human engineering for design of systems, equipment and facilities, only covers general features of console design, such as dimensions and weight. It is not adequate in terms of selection of NKIDs. Accordingly, the aim of this study is to identify the factors effecting user satisfaction and generate design recommendations based on operators' preferences to help designers for the selection of NKIDs in military. Also, to determine which NKID is appropriate for platforms of Land, Navy and Air will be helpful to guide designers and users.

So, the research question of the thesis is:

- What are the design criteria for NKIDs in military use with regard to user satisfaction?

There are some sub questions to examine the main question in detail. Sub questions that will be answered with the field study are:

- Which factors are significant for usage of NKIDs in military concerning user satisfaction?
- Which NKIDs are preferred over the others with the platforms of Land, Navy and Air?

Sub questions that will be examined with literature review study are:

- How are NKIDs evolved throughout history?
- What are the determinants of user satisfaction?
- How is user satisfaction measured?
- How are the NKIDs used in military?

1.3 Significance of the Study

Usability of a computing system has an effect on the performance, so the success, of a user. There are some determinants of usability, such as functionality and satisfaction and to identify these determinants, researchers have made measurement studies on usability. These studies are mainly related to performance and satisfaction of the users. However, from a different point of view, there is a limited number of comprehensive works in the literature analyzing user satisfaction for military products. Especially, in military industry, usability is a crucial factor for success of a mission and usability of the computing system affects the user performance positively.

Accordingly, in ASELSAN, which is one of the largest electronic companies in Turkish defense industry, the success of most projects is related to operator console which *mediates* a dialogue between computing system and operators. As mentioned before, basically, an operator console consists of a screen, a keyboard, a touchscreen, a knob and a pointing device. Although HCI literature claims that selection of these devices affect the performance, there is lack of applications in military on this issue. Therefore, military industry needs empirical research to guide designers. The author of this thesis is a console designer in ASELSAN. For this sake, it can be said that with this thesis study, designers will be able to understand effective factors for user satisfaction on non-keyboard input devices and it will be possible to make some assumptions on the choice and integration of these devices.

1.4 Structure of the Thesis

This thesis consists of five chapters.

First chapter presents the scope of the thesis and the proposed research questions.

In the following chapter, the literature review study is presented in two parts. The first part focuses on non-keyboard input devices (NKIDs) and summarizes history of computer together with input devices and measurement studies on NKIDs in Industrial Design and Human Computer Interaction (HCI) literatures. The first part finishes with a brief summary of usage of NKIDS in military. The second part deals with the user satisfaction. It explains definitions, determinants and measuring methods of user satisfaction in detail.

Chapter 3 presents the design and conduct of the field study. The literature is supported by both a quantitative and a qualitative research studies. This chapter covers two parts, namely the preliminary and the main study and also, ends with results and analysis of the research studies.

In Chapter 4, general discussion is presented. The responses of operators are analyzed both quantitatively and qualitatively and the results are compared.

The thesis concludes with the summary and evaluation of the findings and presents suggestions for further research and limitations of the study.

CHAPTER 2

LITERATURE REVIEW

This chapter begins with a detailed review of non-keyboard input devices and continues with the issue of user satisfaction. The first section deals with historical background, types of non-keyboard input devices and measurement studies related with them. Also, this section examines usage of non-keyboard input devices in military. The second section concentrates on the review of usability, measurement methods of subjective usability, the definition of user satisfaction and determinants of user satisfaction. In addition, the last sub-section focuses on the correlations between user satisfaction measurement studies and non-keyboard input devices to examine the scales and methods related with the thesis subject.

In order to have a broader perspective, relevant literature was scrutinized for the period of 1980-2012 through METU and Aselsan Inc. Libraries and different electronic databases such as EbscoHost, ACM Digital Library, Elsevier, Science Direct, and major periodicals about defense by using broad variety of keywords such as user satisfaction, usability, input devices, subjective measurement, pointing devices, pointer, human computer interaction, military requirements, military standards, human engineering, usability in military products, rugged products, military environment, military consoles, military shelters, military platforms, human factors in military.

2.1 Human Computer Interaction (HCI)

HCI is a discipline interested in interaction between people and computing technology which refers to all activities that include designing, constructing and programming computers (Olson & Olson, 2003). HCI discipline deals with the computing system design and generating useful, usable and aesthetically pleasing hardware and software products. HCI discipline also studies how these products affect their users; so, it measures effectiveness, efficiency and pleasure of these products on users (Olson & Olson, 2003). As Carroll (1997b) defines,

"*Human-Computer Interaction (HCI) is the study and the practice of usability. It is about understanding and creating software and other technology that people will want to use, will be able to use, and will find effective when used."* (pp. 501).

In the marketing literature, HCI discipline has a crucial effect on the success of computing products with regard to safety, usefulness, and pleasure in using those products. There is considerable amount of empirical evidence that implementation of HCI discipline can dramatically decline costs and gain in productivity (Myers, et al, 1996).

When history of HCI discipline was analyzed in the literature, it was realized that it emerged within computer science in 1980s and had a great deal of influence on computing (Myers, 1998). According to Carroll (1997a) "*HCI is the visible part of the computer science*" (pp 62). In other words, human-computer interaction exposes what happens when specific target users begin to use a specific system for specific functionality (Carroll, 1997b). Briefly, it is all about interaction between human and computer.

Computer idea was developed by Vannevar Bush in 1940s. The American Heritage Online Dictionary of the English Language defines the computer *as "A device that computes, especially a programmable electronic machine that performs high-speed mathematical or logical operations or that assembles, stores, correlates, or otherwise processes information"* In 1950s, early computers were used for activities of management, programming and operation. These three activities became major subjects for HCI studies. Then, as mentioned in Table 2.1, in 1980s, the first commercial computers (microcomputers) were developed and usability became major problem (Sears & Jacko, 2008).

Table 2.1 Developments Observed in Digital Computers (Shackel, 1997)

Computer type	Approx growth era	Main Users	User Issues
Research machines	1950s	Mathematicians Scientists	Machine reliability; users must learn to do the programming
Mainframes	1960s & 1970s	Data-processing professionals supplying a service	Users of the output (business managers) grow disenchanted with delays, costs, lack of flexibility
Minicomputers	1970s	Engineering and other non-computer professionals	Users must still do much programming; usability becomes a problem
Microcomputers	1980s	Almost anyone	Therefore usability is the major problem
Laptops Notebooks PDAs	1990s	Anyone and often in mobile situations	Complexity in trying to achieve usability, especially with new input/output modalities

Before invention of the commercial computers, computers were in the size of a large room, consuming as much power as several hundred modern personal computers (Figure 2.1). These mechanical analog computers were used as business machines which were produced for data processing professionals. With personal computers, everyone began to use computers. In addition, the rapid increase in personal computers' usage caused some problems related to insufficiencies of computers and allowed for the emergence of a new field, usability (Shackel, 1997). In this context, Shackel (1997) claims that in late 1950s, HCI research was done primarily on military computer systems with respect to human factors and usability aspects. Also, ergonomics discipline was concerned with design and the usage of manual control devices, such as buttons, switches and displays in aviation (Sears & Jacko, 2008). However, there had not been any improvement on the design of the commercial computer systems until 1960s.

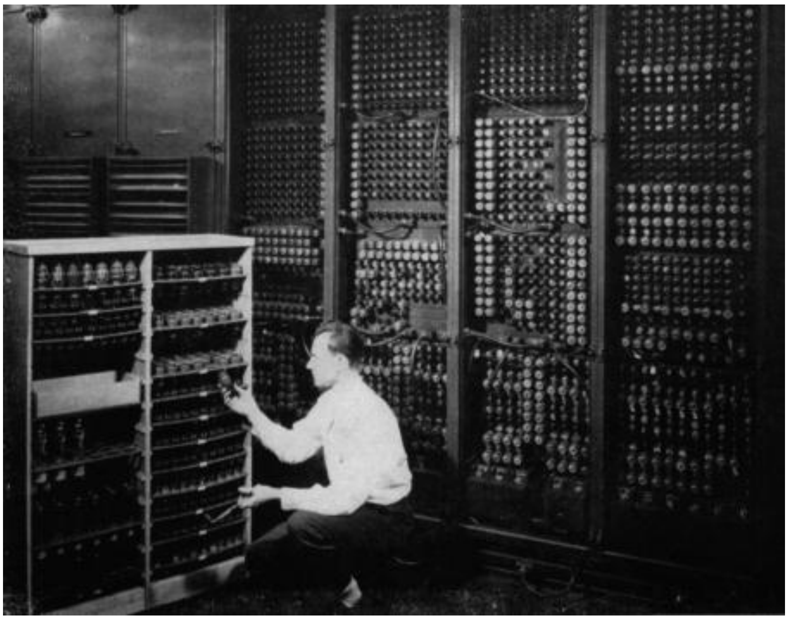

Figure 2.1 First Generation Computer (retrieved from http://www.plantsciences.ucdavis.edu/amr21/AMR21newsite/AMR21/NewEALpages/Lect03.html)

As aforementioned above, when early computers were used for military operators, HCI discipline began to be interested in need of pilots in aviation systems. With the development of aircraft technology, systems became more complex and so, interface issues became more critical. In the 1970s, computers were used in commercial aircrafts. As a result, new types of interfaces were steadily added to aircrafts. Therefore, this continuous progression of interfaces created new challenges associated with HCI discipline (Sears & Jacko, 2008).

Today, HCI discipline has a large effect on the success of systems in the market because of increase in computer usage and safety issues of companies that use computing systems (Acarturk & Cagiltay, 2006). Therefore, HCI discipline has developed a large volume of input and output techniques over the last few years.

Human-Computer Interaction Domains

Usability is "*the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."* (ISO 9241, 1998, pp 2).

This is the basic definition of usability according to ISO standards. Designing more usable systems is essential in the industry in order to increase productivity, reduce errors and improve acceptance by the users. Therefore, it has gained increasing importance in HCI literature (Shackel, 1997). Although the importance of usability receives significant recognition, there is still confusion over the meaning of the term. Researchers have defined usability in many ways. These terms and definitions will be analyzed in detail in the second part of this chapter.

HCI is a discipline and practice of usability. To satisfy the need of usability, HCI discipline examines human behaviors in many aspects. Because of the complexity of an individual in interaction with a machine, HCI discipline divides user activity into three different levels namely physical, cognitive, and affective levels. The existing physical technologies develop the devices, namely input and output ones are basically based on three human senses: vision, audition, and touch (Karray et al, 2008).

In a computing system, there are input and output devices that establish a connection between the system and the world. Input devices are generally based on vision and they are commonly switch-based or pointing devices. Mouse, joystick, touchscreen, graphic tablet and trackball can be provided as the examples of input devices whereas monitors and printers can be provided as the examples of output devices in a computer (Karray et al, 2008). In the next section, history and types of input devices will be examined in detail.

2.2 Input Devices

Input to computers includes information about physical properties of human, environment and things. Input devices can be defined as a way to provide the information to an interactive system by performing a specific task and get feedback from the system (Hinckley, 2002).

Each input device has different properties. This variety in input devices requires special effort for designers to choose the suitable one that matches the demands of user and task requirements (Buxton, 2010). Hence, a designer who understands input technologies and the task requirements of users has a better chance of designing input devices or making the appropriate selection from existing input devices. Also, the designer should take into consideration the physical properties, the feedback conducted for the user, the design features of the device, and all the interaction techniques between users and system to avoid usability problems (Hinckley, 2002).

2.2.1 General Properties of Input Devices

Each input device has different specialties, such as its form, size, mode and cursor velocity function. However, most of them can be characterized by some properties. Some of them are engineering parameters including resolution, accuracy, device acquisition time, sampling rate, latency, noise, aliasing, nonlinearity, absolute vs. relative, control to display ratio (gain), physical property sensed and so on. But also, there are comfort and user preference issues, which are rarely examined in the literature (Hinckley, 2002; Hinckley et al, 2008). Thus, main interest of this study is user preference issues related to input devices.

2.2.2 Evolution of Input Device Technology

A wide variety of communication channels have been developed to make contact between human and computer during the years. Although it is not known when the exact creation time of some devices as light pen and joystick, there were only keyboards at the beginning. Then, in 1950s and 1960s, light pen, joystick, trackball, mouse appeared as the first generation input devices and touchscreen followed them in the seventies.

Beginning of studies on input devices is a result of improvement of interface design. Before the advent of interface design, ergonomics discipline was concerned with manual control devices, such as buttons, switches and displays in vehicle control and aircraft piloting. Since the late 1970's, studies on input controls have been involved as a part of HCI discipline. Firstly, Card, English, and Burr (1978) made a study on the performance of various input devices. Then, till now, studies of input devices have been developed with the contributions of researchers by releasing journals and papers (as cited in Zhai, 2009). However, this caused little development although input devices had a great potential to be improved (Buxton, 2005). Then, a significant trend towards touchpads has begun. The main feature of these devices is that they can be used by both hands (Buxton, 1994). Consequently, it can be stated that input technologies will continue to change so long as the technology keeps its growing.

2.2.2.1 Keyboards

The history of keyboards has begun with the invention of typewriters over a century ago. Christopher Latham Sholes invented them in 1868 and he also developed QWERTY key layout, which have been used commonly in modern keyboards today (Figure 2.2). Then, a wide variety of keyboards was created but modern keyboards are still loyal to original ones despite a few minor changes (Guiard & Beaudouin-Lafon, 2004).

Figure 2.2 Standard QWERTY Keyboard (Zecevic, 2000).

A keyboard is a basic input device to enter text and characters into an interactive system. It has mechanical switches. Generally, it is used with other input devices, like mouse (Bogue, 2011).

Performance of keyboards can be influenced by many factors, such as size, shape, tactile of the device. These factors have been analyzed for years. Today, new trends are taken into consideration to improve user comfort and input efficiency of input devices (Hinckley, 2002). One of these is related to ergonomic factors. Manufacturers began to take into account user comfort and they reproduced keyboards by adding new features, such as angled arrangements, resizing and replacing keys, adding wrist resting pads, and increasing tactile key-level feedback. Other trend is the change of keyboard size. With new technologies, keyboards were re-modeled to be compatible with personal digital assistants (PDA) and mobile telephones and so, they were minimized (Schedlbauer, 2007). Although most users prefer standard QWERTY keyboards, as mentioned before, a wide variety of keyboards have been produced because of new interfaces. Some of these keyboards will be explained in the next paragraph.

Split-angle keyboards were produced to preserve neutral wrist position to avoid disorders and injuries (Zecevic et al, 2000) (Figure 2.3). With the increase in mobile computing devices' popularity, *miniature keyboards* were created. They are small foldable keyboards for handheld devices as shown in Figure 2.3b. Another type of keyboard is the wireless one that enables people to use it far away from display

(Hinckley, 2002). Moreover, some pointing devices were integrated into keyboards. An embedded isometric joystick or touchpad led users to use keyboards without removing their hands from them. Also, it is useful for limited spaces. Another one was invented for disabled users and compact computers. *One-handed keyboards* (chording) are special half keyboards with all functions (Matias, 1994) (Figure 2.3c). Finally, *soft keyboards* are generally used with mobile devices. It is possible to type with a touchscreen or stylus. In some cases, some soft keyboards like in Figure 2.3d are foldable to be used with computers (Sears & Zhai, 2010).

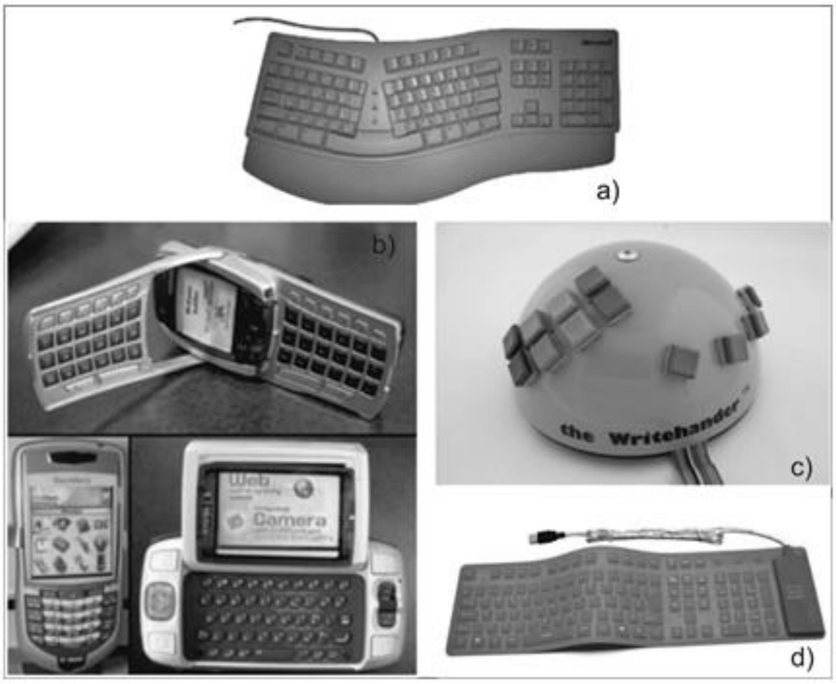

Figure 2.3 a) Split-Angle Keyboard (Zecevic, 2000); b) Miniature Keyboards in Mobile Phones (Clarkson et al, 2005); c) One-Handed Keyboard (Buxton, 2012); d) Soft Keyboard (retrieved from www.diytrade.com)

The most fundamental input device for an interactive system is keyboard. As mentioned before, a keyboard is commonly supported by another input device. In fact, today, touchscreens are started to be used instead of keyboards for some applications (Bogue, 2011).

Besides keyboards, there are a wide variety of non-keyboard input devices, such as light pen, mouse, joystick, pointing stick, touchpad, trackball. All of these devices have specific advantages and disadvantages for different purposes. Their common disadvantage is occupying too much space. So, designers began to integrate one or more input devices into keyboards. In some cases, these integrated products are inadequate to satisfy an interactive system's needs and so, it is needed to choose another input device like mouse. Especially for military, designers should be able to decide a suitable input device for operation due to saving space, making users comfortable and being successful in missions (Mishra, 2006). In the next section, most commonly used NKIDs will be examined in detail.

2.2.2.2 Non-Keyboard Input Devices

NKIDs are generally used together with keyboards and they were created with different features. As mentioned, at the beginning, there were only keyboards, but in 1950s and 1960s, the first input devices including light pen, joystick and mouse were developed. Then, first touchscreen and similar devices appeared in the 1970s. The detailed information about light pen, joystick, mouse, trackball, pointing stick, tablets, touchpad and touchscreen were provided in the next sections in appraisal chronological order. Moreover, alternative input devices and future trends were examined.

Light Pen

Light pen was the first pointing input device used for computers in 1949. However, it was used for different purposes in 1930s. It is based on optics. It consists of photo sensor that realizes the changes on the screen and forwards as a signal. Then, changing time is measured by the computer and it updates coordinates of light pen's position (Huddart et al, 1965) (Figure 2.4). Users can both draw and write with light pen. But it requires more effort to use when compared to other input devices (Zhai, 2004). With similar working principle, light gun was developed from light pen. Unlike light pen, light gun can be used a bit away from screen position (Huddart et al, 1965).

Figure 2.4 A Light Pen (retrieved from https://www.asme.org/engineering-topics/articles/computer-aided-design-%28cad%29/the-future-of-design)

Joystick

Like light pen, exact time of joystick's invention is not known. It has not showed a great improvement during the years. But, their usage has been changed (Figure 2.5b & Figure 2.5c). The initial ones were mechanical and used in aviation during the first years of the 20th century. Then, in 1940s, mechanical joystick turned into electronic one with World War Two. German army used this joystick for tele-guided missiles. Then, in 1961 Alan Kotok designed the joystick for a different usage area, video games (Wolf, 1988).

The first joystick was placed in a big box (Figure 2.5a). The working principle is based on two potentiometers used to control electrical devices. They are placed perpendicular and follow horizontal and vertical movement of the pointer. The potentiometers are controlled by two sticks and so, two hands are used. Also, first joystick has a button to select the target on the screen (Graetz, 1981).

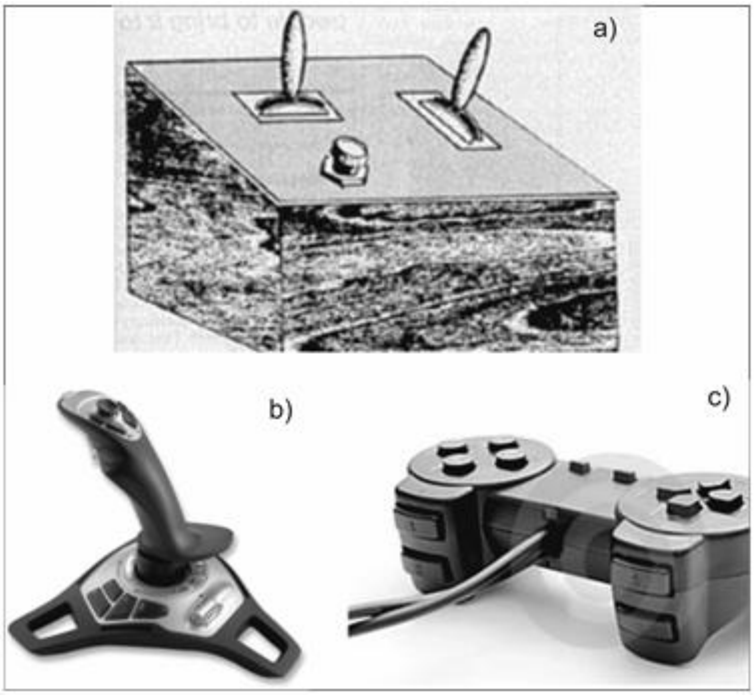

Figure 2.5 First Joystick (retrieved from http://www.1jma.dk/articles/1jmaluftwaffegroundweapons.htm); b) Modern Joystick in 1900s (Schedlbauer, 2007); c) Game Joystick Sample (http://www.dreamstime.com/stock-image-modern-joystick-image19154911)

There are two types of joysticks, isometric and isotonic (Schedlbauer, 2007). *Isometric Joystick* is a joystick that when applied force it does not move. *Isotonic Joystick* is an angle sense joystick unlike isometric ones (Hinckley, 2002).

Trackball

The invention of trackball was in 1952. It was invented for a military project (Hinckley, 2002). A trackball moves upside down like mouse. It is mounted on the surface where used in; namely panel mount (Figure 2.6a). So, it cannot be moved. It consists of a ball located in a socket with sensors and few buttons located around the ball (Bogue, 2011). Recently, trackballs are smaller than older trackballs due to mount on laptops (Schedlbauer, 2007). In fact, they are preferred for limited spaces. They are preferred for both military and civil applications, such as sonar and radar systems, industrial and scientific instruments, vision systems, laptops, cell phones and gaming consoles (Bogue, 2011) (Figure 2.6b & Figure 2.6c).

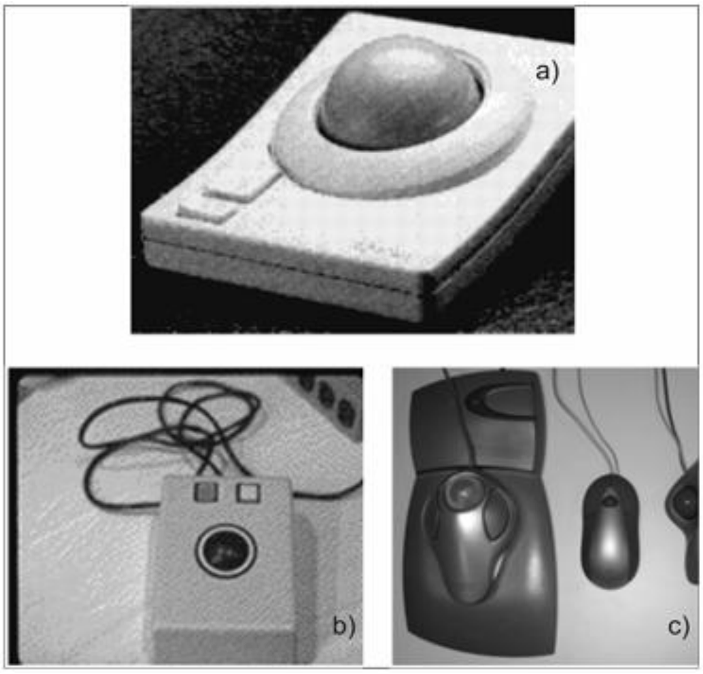

Figure 2.6 a) Standard Trackball Sample (Buxton, 2012); b) Military Trackball Sample (Buxton, 2010); c) Modern Integrated Trackball Samples (Isokoski et al, 2007)

Mouse

As mentioned before, mouse was the last of first generation input devices. It was invented by Douglas Englebart and his colleagues in the early 1960s. The purpose of its invention was to develop a computer operation so that inventors created cheaper alternative for light pen. First mouse was made of wood and wheeled as shown in Figure 2.7a and it was so big as compared with today's standard mice (Jessen et al, 2010). With the invention of computer AEG-Telefunken TR 440 in 1970 at the University of Bochum, ball mouse was appeared by Xerox PARC in 1972 (Palo Alto Research Center Incorporated) (Figure 2.7b), which is a research and development company in California (Zhai, 2004). Then, mouse was produced commercially as a part of the Xerox Star (1981) (Figure 2.7c), the Three Rivers Computer Company's PERQ (1981), the Apple Lisa (1982) and the Apple Macintosh (1984) (Figure 2.7d) (Jessen et al, 2010). After Apple Macintosh's mouse which was the updated version of the Apple Lisa, the mouse became a more commonly used device (Bogue, 2011).

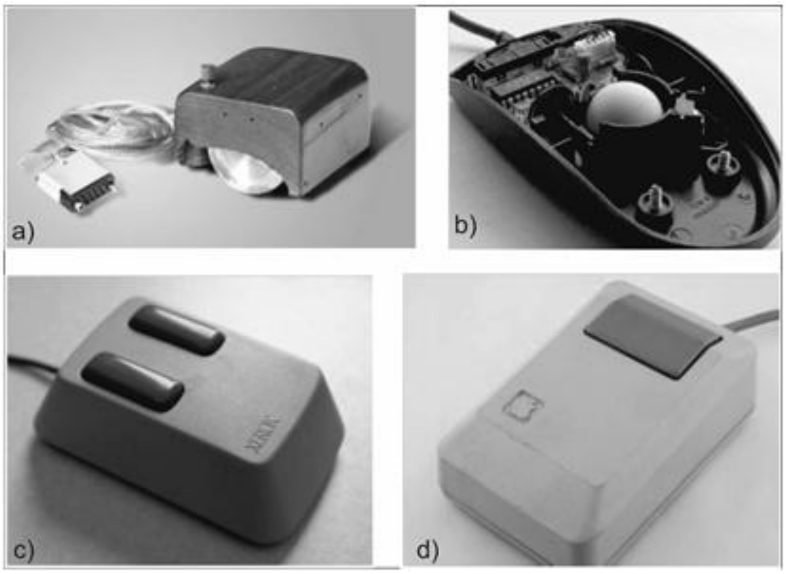

Figure 2.7 a) First Mouse in 1960s (Buxton, 2012); b) The Mechanism of Ball Mouse (Zhai, 2004); c) The XEROS Star Mouse in 1981 (Zhai, 2004); d) Apple Macintosh's Mouse in 1984 (Buxton, 2012)

Considering the older and newer versions of mouse, it can be said that movements of older mouse were limited to horizontal or vertical but the ball provided more freedom in the movements of users, such as forward-backward motion and left-right motion. These versions were mechanical mouse. After Xeros PARC invented optical encoder, optical mouse was developed in 1981 (Figure 2.8a). The working principle is based on a chip that includes image sensors and motion detection. First, the chip captures photos with the help of image sensor and then, it compares images in order to measure movements of the mouse (Bogue, 2011). These optical mice were more durable than mechanical ones. Because the mechanism was hidden, dirt and dust could not go into the mouse. Also, optical mouse were cheaper due to requiring less material. In 2001, Microsoft produced an optical mouse, “IntelliMouse”, which was the first commercially successful mouse. Then; scrolling mouse, laser mouse, cordless mouse and wireless mouse were developed (Bogue, 2011) (Figure 2.8b, Figure 2.8c & Figure 2.8d).

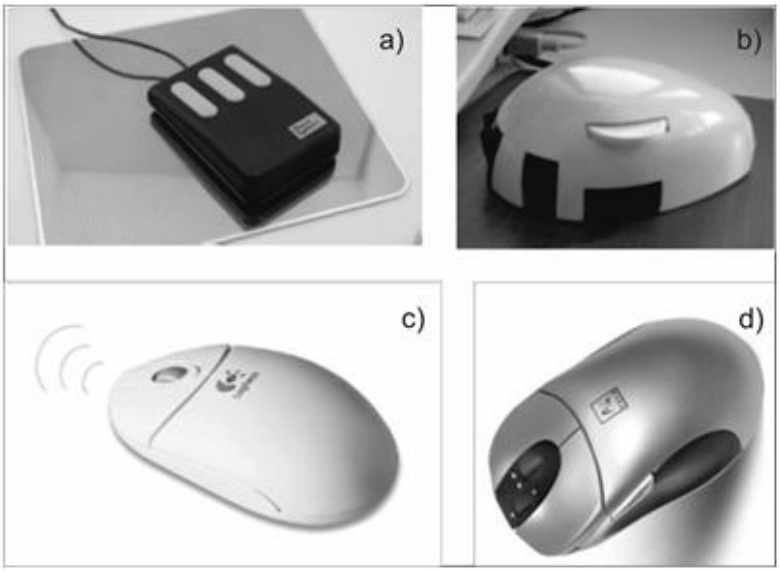

Figure 2.8 a) First Optical Mouse in 1981 (Buxton, 2012); b) First Scrolling Mouse in 1985 (Buxton, 2012); c) Cordless with Scroll Wheel Mouse in 1990s (Buxton, 2012); d) Wireless Mouse in 1990s (Buxton, 2012)

Still today, many companies continue to develop different kinds of mouse, such as 3D mice, which is known as bat (Figure 2.9). Although there are wide variety of alternative input devices that have been developed during the years, the mouse have been used more commonly because it satisfies most of the needs of systems and users. For example, users apply less force with the mouse compared to other devices (Hinckley, 2002). Also, the mouse provides better coordination between cursor and target, therefore it is easy to use but touchscreens or display tablets have display surface on the input surface and do not include buttons so; it is hard to use but they are more durable because they do not have a mechanical intermediary that can be lost and break down. For mouse, joystick, or stylus, user moves the cursor and selects the target on the screen. They do not have any display surface on them (Hinckley et al, 2008).

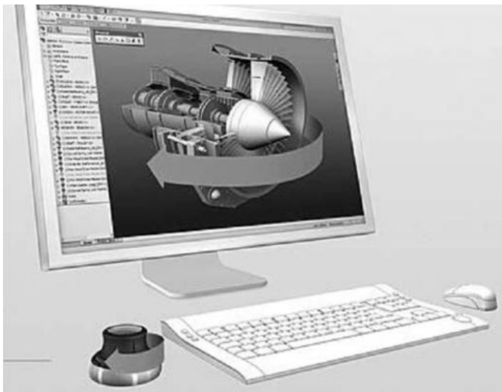

Figure 2.9 3D Mouse Sample (Bogue, 2011)

As a result, with the development of mouse, different fields such as ergonomics became to be interested in. The form and size of a mouse are the important factors for the usability of it. Also, they have particular effects on purchase decisions of consumers (Zhai, 2004).

Track Point or Pointing Stick

Pointing stick is, generally, mounted on laptops and notepads. It was patented by International Business Machines Corporation (IBM), which is a company producing hardware and software for the computers since 1911 (Bogue, 2011) (Figure 2.10). The working principle is similar to an isometric joystick. It is a force sensing device and useful for only pointing. So, it is functional when it is embedded in the laptop's keyboard (Zhai, 2004).

Figure 2.10 IBM Track point (Zhai, 2004)

Hula Pointer

Hula pointer has similar working principle with pointing stick, mainly used for military applications. But as an advantage, it has bigger buttons (Figure 2.11). They have similar functions of mouse' buttons.

Figure 2.11 Hula Pointer Sample (retrieved from http://www.ikey.com/pointing-devices)

Tablets, Touchpads and Touchscreens

Tablets are touch sensitive devices that are variously known as touch tablets, graphics tablets, or digitizing tablets (Figure 2.12). They are smaller mobile computers. They have been developed since mid-20th century. They can be used by bare finger or a stylus. They are useful for many tasks, such as drawing, handwriting, tracing, or digitizing (Hinckley, 2002). Also, they can be combined with other input devices such as keyboard or mouse (Buxton, 2009).

Figure 2.12 Tablet Sample (Buxton, 2012)

Touchpads are smaller tablets commonly mounted on laptop computers (Figure 2.13). Their functions are similar to mouse. They state motion and position with finger or stylus and they send signal to computer (Bogue, 2011). They are commonly supported by a mouse (Schedlbauer, 2007).

Figure 2.13 Touchpad Sample (Bogue, 2011)

Touchscreens are tablets that are translucent and embedded on a display (Figure 2.14a). First one was developed in 1960s by IBM (Bogue, 2011) (Figure 2.14b). Firstly, they were used in labs and computer centers. Then, in 1972, they were transferred into grade-school classrooms with the invention of PLATO IV (Programmed Logic for Automatic Teaching Operations). PLATO IV was the first step taken of personal computers. Through the 1970s-80s, different companies had developed touching technologies and commercialized them (Buxton, 2010). Touchscreens are supported by bare finger or stylus and their working principle is similar to tablets (Hinckley, 2002). They do not have buttons and so, it is hard to drag, drop, and scroll (Schedlbauer, 2007).

Figure 2.14 a) Touchscreen Sample (Schedlbauer, 2007); b) First Touchscreen in 1960s (Buxton, 2010)

After the inventions of touchscreens and touchpads, they have been preferred instead of keyboards and other input devices. It is thought that they will be the future of human computer interaction with technological advancements (Hahn, 2010).

2.2.2.3 Alternative Pointing Devices

With advancements in technology, researchers began to look for alternative pointing devices for different users, tasks and purposes. For example, for disabled users, eye tracking technique was explored as an alternative pointing. Recently, researchers have been studying on feet for input, head tracking, eye tracking and direct brain interfacing techniques. But, experimental studies are very limited. Thus, they are not ready to be used widely, yet (Hinckley et al, 2008).

2.2.2.4 Future Trends

Beginning from the 1980s, investigation has been carried out on 3D input devices. These devices can create three dimensional images on the screen. Bat mouse, space ball, haptics, 3 degrees of freedom (dof) haptic paddles and 6 dof haptic paddles are the examples of 3D input devices (Buxton, 2012) (Figure 2.15).

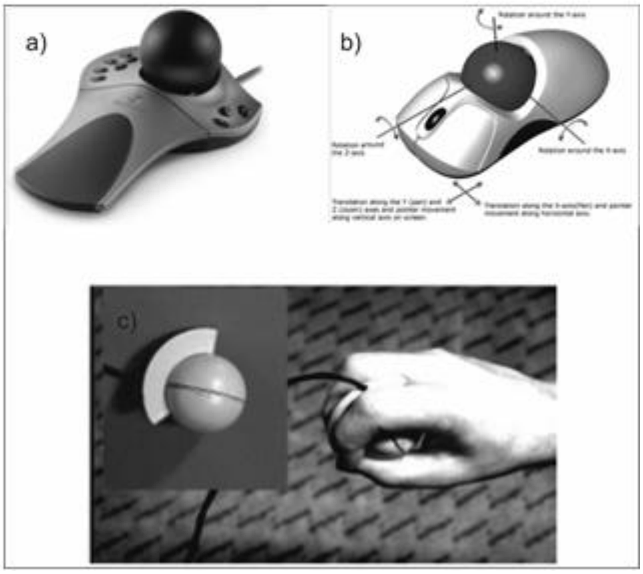

Figure 2.15 a) Space ball Sample (Zhai, 2004); b) 6DOF Mouse Sample (Buxton, 2012); c) Apple 6DOF Mouse (Buxton, 2012)

2.2.3 Evaluation and Analysis of Input Devices

In HCI literature, there are some techniques for the analysis of input devices. These techniques analyze devices formally or informally. Especially formal analyses such as Fitts’ Law, Hick’s Law, Steering Law and Minimum Jerk Law are used to measure and compare performances of input devices. The most commonly used formal analysis is Fitts’ Law (Hinckley, 2002). Other types consist of complex engineering formulas; however, they are also based on Fitts’ Law. Therefore, it would be valuable to explain Fitts’ Law among these techniques to have general opinion on this issue.

Fitts' Law

In 1954, Paul Fitts described Fitts' Law which has been used for the comparison and optimization of pointing devices. It defines how effectively an input device can point targets on the screen by measuring movement time between two targets. At first, Card, English, and Burr used Fitts' Law in their study of input devices in 1978. Then, comparing performance of input devices became standard for researchers (Hinckley, 2002).

Speed, which is related to movement time of user hand, is one of the main criteria used to measure the performance and so, Fitts' Law is a paradigm for guessing movement time for input devices (Jacob, 1996). According to Gokturk (2011), the performance is related with the speed which is defined by the movement of the cursor to the target. Fitts' Law is interested in the time passed for moving to the target, the movement distance from the starting point to the target and lastly the target width. In most studies, NKIDs related experiments are conducted considering the Fitts' Law.

Gokturk (2011) defines Fitts' Law as follows:

"MT represents the movement time to hit the target, a and b are empirically determined constants. A represents the amplitude, which is the distance of the center of the target from the starting location and W is the target width" (pp1) (Equation 2.1 &Figure 2.16).

$$\boxed{MT = a + b\log_2(2A/W)}$$

Equation 2.1 Fitts' Law

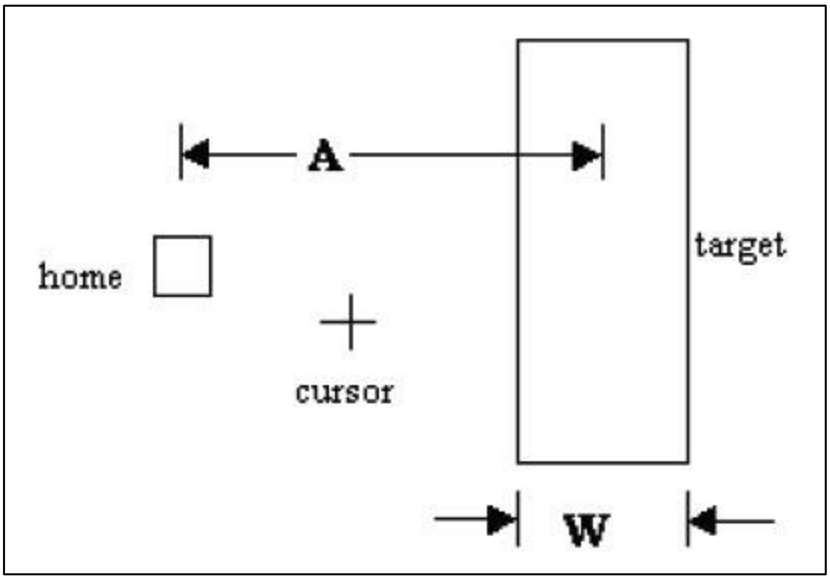

Figure 2.16 The Basic Pointing Task Variables A and W

Guiard and Beaudouin-Lafon (2004) claim that Fitts' Law is highly practicable in HCI because it predicts movement time of the pointer to reach a defined target. HCI researchers used Fitts' Law in two ways; a predictive model and a means to derive the dependent measure (Soukoreff & MacKenzie, 2004). In the first way, Fitts' Law is used for guessing movement time of a user to move a mouse and click on it. It is an invaluable way to design interface. The second way, Fitts' Law is used in HCI to evaluate pointing devices by comparing them. For comparing, several movement times are measured and then, how the different conditions affect the coefficients within the Fitts' Law relation is determined by researchers (Soukoreff & MacKenzie, 2004). Studies carried out on these input devices will be analyzed in detail in the following sections and in the upcoming section, elemental tasks used in NKIDs studies will be examined.

Elemental Tasks

Some basic activities are performed repeatedly in use of input devices, such as texting or selecting although there are many activities supported by computers. These basic activities are called elemental tasks. There are well known six elemental tasks, which are identified by Foley, Wallace, and Chan in 1984. Then, many researchers began to use these tasks to evaluate input devices (Hinckley, 2002; Hinckley et al, 2008).

Select is to point the object(s) from options, *position* is specifying on position screen coordinate, *orient* is to rotate, *path* is citing a series of positions or orientations, *quantify* is specifying a single numeric value, *text* is entering symbolic data as characters or numbers.

Elemental tasks should be certainly defined because they help to structure more suitable match between users and interactive systems. Accordingly, the choice of device and technique affects the demands of users and interface design features (Hinckley, 2002; Hinckley et al, 2008).

2.2.4 Ergonomic Issues for Input Devices

Zhai (2009) claims that most computer workers suffer from repetitive strain injury (RSI). Researchers associate these injuries with manual operated devices and repetitive activities because the size and shape of a physical device has particular implications towards which the particular muscle groups (limbs) used in manipulating the device, including the wrist, the arm, the hand, and the fingers. Therefore, in their studies, they advise some ergonomic design themes such as reducing repetition, minimizing force required to use the devices, avoiding sharp edges, designing for postures of the user’s hands and wrists and having cues for use (Hinckley, 2002; Hinckley et al, 2008). These studies will be examined in more detail in the next section.

2.2.5 Standards and Research Studies on NKIDs

Today, a wide variety of non-keyboard input devices have been commercialized in the market. To select the most suitable one for users' needs, many researchers make comparisons to describe and analyze input devices. Most of these studies are based on performance models. For objective evaluation, as mentioned previous section, Fitts' Law is used to measure motor performance of input devices and compare those (Sutter & Ziefle, 2005).

Since 1954, Fitts' Law has been extensively used in *experimental psychology, human factors, and human–computer interaction* (Soukoreff & MacKenzie, 2004). HCI also developed applicability of Fitts' Law in researches carried out on input device ergonomics (Guiard & Beaudouin-Lafon, 2004).

In early studies, researchers made analyses on mouse as a major device. They compared mouse with other devices in regard to performance related with dimensions, such as movement time, error rates and speed. First of these studies was carried out by Card, English, and Burr in 1978. They tested four devices, mouse, keyboard, and two joysticks. In the experiment, selection time, error rates, and learning time were measured. The result indicated that mouse was the best in terms of speed and accuracy (as cited in MacKenzie, 1992; as cited in Sperling & Tullis, 1988).Similarly, in 1986, six input devices including a trackball, a mouse, two touchpads and two joysticks were compared by Epps. He found that mouse and trackball were faster than others; but, there was not any significant difference between the two. In both studies, mouse showed higher performance than others (as cited in MacKenzie, 1992; as cited in Sperling & Tullis, 1988).

On the other hand, most of the previous studies do not take user satisfaction into account. Input devices have been scarcely investigated from user satisfaction point of view. Sperling & Tullis (1988) compared mouse and trackball in terms of speed and accuracy. Also, they analyzed user experience and user satisfaction by considering the performance of these devices. According to results of this study, there were not any considerable differences between them in terms of accuracy. But, with regard to user experience and user satisfaction, mouse was preferred by the participants.

In the recent studies, with the development of new devices such as tablets and touch pads, researchers began to make new comparisons. Ichikawa et al (1999) compared mouse and tablet operation through the experiments on pointing time, accuracy, mental work load and psychological easiness to operate. They revealed that tablet had a shorter pointing time but the mouse was superior for psychological easiness to operate. Moreover, some devices, such as touchpad and track point were integrated into keyboards or the chassis of computer notebooks. There is a large amount of published studies analyzing these devices to measure psychomotor performance of both inexperienced and experienced users. The outcome of all these studies indicated that the touchpad performance was higher than mini-joystick performance. These results were significant to guide designers about usage and design of the mini-joystick and touchpad devices (Sutter & Ziefle, 2005).

The results of mentioned studies varied and so, it is difficult to determine advantages and disadvantages of input devices. It is clear that task differences, selection technique, users' expertise, range of conditions and choice of model, approach angle, target width, error handling learning effects are the reasons of this variation (MacKenzie, 1992). Because of a great number of published studies, it is hard to compare and categorize the outcomes of studies. Therefore, a standard for input devices was published for solving this problem.

ISO 9241 standard, "*Ergonomic requirements for office work with visual display terminals"*, covers 17 parts (MacKenzie & Oniszczak, 1998). Part 9 is called *"Requirements for non-keyboard input devices"* and it contains instructions in order to evaluate usability of input devices. It claims that user performance and satisfaction has to be analyzed with the aim of evaluating usability (Baldus & Patterson, 2008). Therefore, it describes both quantitative and qualitative test methods for measuring *performance*, *comfort*, and *effort* of input devices. The procedure of a quantitative test is that users carry out defined tasks and their performance are measured. For a qualitative test, users fill out a questionnaire about their comfort and satisfaction (MacKenzie, 2009). This questionnaire consists of 12 questions to assess input devices in regard to physical operation, accuracy and speed, fatigue and comfort and overall usability. (Table 2.2 ISO Device Assessment Questionnaire Sample (Douglas et al, 1999). Although there are alternative usability scales for the evaluation of input devices, ISO 9241-part 9 provides more appropriate questionnaire to assess the input devices.

Table 2.2 ISO Device Assessment Questionnaire Sample (Douglas et al, 1999)

DEVICE ASSESSMENT

Please circle the x that is most appropriate as an answer to the given comment.

1.	The force required for actuation was					
		x	x	x	x	x
		too low				too high
2.	Smoothness during operation was					
		x	x	x	x	x
		very rough				very smooth
3.	The mental effort required for operation was					
		x	x	x	x	x
		too low				too high
4.	The physical effort required for operation was					
		x	x	x	x	x
		too low				too high
5.	Accurate pointing was					
		x	x	x	x	x
		easy				difficult
6.	Operation speed was					
		x	x	x	x	x
7.	Finger fatigue:					
		x	x	x	x	x
		none				very high
8.	Wrist fatigue:					
		x	x	x	x	x
		none				very high
9.	Arm fatigue:					
		x	x	x	x	x
		none				very high
10.	Shoulder fatigue:					
		x	x	x	x	x
		none				very high
11.	Neck fatigue:					
		x	x	x	x	x
		none				very high
12.	General comfort:					
		x	x	x	x	x
		very uncomfortable				very comfortable
13.	Overall, the input device was					
		x	x	x	x	x
		very difficult to use				very easy to use

As mentioned in ISO standard and Ergonomics, some studies carried out on input devices are about comfort of users. Related disorders with the usage of input devices are mainly musculosketal having effects on posture, which is upper limbs (neck, shoulders, arms, hands/wrists), back and lower limbs (knees, hips) and it can cause pain and discomfort (Woods et al, 2002). Nine health organizations made a research on commonly used non-keyboard input devices with office workers. Woods et al

(2004) reported that 45% of mouse users and 16% of other types of device users had musculoskeletal pain and discomfort. Another study showed that mouse design had a huge effect on task performance, wrist extension and subjective ratings of comfort and usability (Hedge et al, 1999).

Apart from quantitative performance evaluation, limited study investigated design and usability of input devices in terms of user satisfaction and user preferences (Woods et al, 2003). Baldus & Patterson (2008) made subjective usability experiments with mouse, touchpad and touchscreen in a moving tractor. Users filled out a questionnaire in relation to overall usability, performance, comfort and suitability for tested environment. As a result, mouse took the highest ratings in subjective usability evaluation whereas touchpad took the lowest. They reported that although the performance of mouse and touchpad was measured in the same, users expressed that they were more satisfied with mouse Table 2.3).

Table 2.3 Questionnaire of user preferences (Baldus & Patterson, 2008)

Q1: How comfortable was the device?		
Mouse (7.22)	Touch pad (5.16)	Touch screen (4.44)
Q2: How accurate was the tested device?		
Mouse (6.72)	Touch pad (4.61)	Touch screen (4.39)
Q3: Rate the speed of the tested device		
Mouse (7.00)	Touch screen (5.78)	Touch screen (4.89)
Q4: Rate the influence of motion on the device		
No significant difference between devices was found		
Q5: Rate the influence of the button size for the device		
No significant difference between devices was found		
Q6: Rate the overall usability for each device		
Mouse (5.78)	Touch screen (4.33)	Touch pad (4.22)
Q7: Please rank the devices based on your preference for the tested environment		
Mouse (1.44)	Touch screen (2.22)	Touch pad (2.33)

Another subjective evaluation was made by Woods and his colleagues in 2003. They studied on mouse, trackball and joystick to determine the factors for input device design in terms of operation, performance and comfort by using questionnaires.

Firstly, three defined tasks were applied by users. Then, a questionnaire including questions about device operation, device performance, device design, device comfort and subjective comments was filled out. Aim of this study was to determine design factors for the best input devices design. As a result, they categorized negative and positive comments and made critical design recommendations for the usage and selection of NKIDs. The results were gathered in order to generate device checklists (Woods et al, 2003).

As mentioned above, there are a great number of usability studies based on performance measurement of non-keyboard input devices. However, there is a limited study for these devices in terms of user satisfaction. In fact, although there is a report including general design criteria for non-keyboard input devices, it does not contain information about user satisfaction and comparative data (Ahlstrom & Kudrick, 2004). Therefore, other researches are needed to compare different input devices in terms of user satisfaction.

2.2.6 Usage of NKIDs in Military

Standards and handbooks are indispensable sources for both military and civil industries. There are wide ranges of standards, such as U.S Department of Defense *(DOD)*, *NATO*, Federal Aviation Administration *(FAR)* and American National Standard *(ASTM)* which are interested in many areas from military shelter to labeling of cables. Among them, Department of Defense Design Criteria Standard (MIL-STD-1472G), Department of Defense Handbook for Human Engineering Design Guidelines (MIL-HDBK-759C) and Standard Shelter Technical Specifications (NATO-6516) are the most commonly used standards and handbooks in product development process. Purposely, MIL-STD-1472G (2012) and MIL-HDBK-759C (1995) include general requirements and criteria for the design of systems and products. Also, they give general information about environmental conditions and test procedures in military. As related to thesis subject, MIL-STD-1472G determines general design criteria for workstation design, *console*, of an operator who is a soldier in a special mission and an expert user of a console. It determines specific dimensions for the console according to the purpose for which it is designed (2012).

An operator console consists of screen, keyboard and pointing device elements. Console is used in air, land and naval platforms as a workstation for operators. As mentioned before the author of this thesis is a console designer in ASELSAN, it would be better to mention that it is difficult to categorize the consoles according to platforms and duty of the operators. Because of different environmental conditions in each platform, some mechanical criteria such as weight and material change for each console but the appearances of the consoles are similar as shown in Figure 2.17.

There are wide varieties of devices used in console designs because MIL-STD-1472G defines general design criteria, for instance, dimensions for console design and it gives insufficient information about the choice of input devices (2012). However, as mentioned in HCI literature, it is a fact that the proper decision and assessment of input devices have a strong effect on the performance of operators. But, the number of research studies carried out on this issue is quite rare in the literature because studies related with the military are limited for some reasons like official secrecy.

MIL-STD-1472G (2012) states that performance reliability and standardizing designs of operators and systems are significant requirements for the success of mission in military. Also, Harris (2006) states that safety and efficiency have an effect on the performance of operators.

Figure 2.17 Consoles Design Samples (taken by in International Defense Industry Expo (IDEF) 2009)

MIL-STD-810G (2008) is a standard used for defining the environmental design and test process in military. Environmental conditions in military are different from civil environment features. Since both weather conditions and high risk factors require much more safety regulations, military designs need to take extreme accuses. For example, in order to reduce effect of vibration and make products more long-lasting, military products are generally made rugged. MIL-STD-1472G (2012) defines ruggedness as "*systems and equipment shall be sufficiently rugged to withstand handling in the field during operation, maintenance, supply, and transport within the environmental limits specified for those conditions in the applicable hardware or system specification*." Also, if a product is not rugged, it is mostly integrated as a panel mount. Especially, input devices, such as keyboards, trackballs, and hula points are integrated as panel mounts devices (Figure 2.18).

Figure 2.18 Panel Mount Device Samples (retrieved from http://www.ikey.com/keyboards/keyboards-panel-mount)

Apart from standards and handbooks about NKIDs, when the literature is scrutinized, it is realized that the number of studies carried out on the usage of input devices in military is limited. Maybe, this situation can be the result of security requirements. But, designers need these kinds of studies to make appropriate choices while designing a console.

The following sections, *usability and user satisfaction*, are directly connected with the subject of this study as it would be helpful to find out the most appropriate measurement tool to evaluate NKIDs presented in the previous part of this chapter.

2.3 Usability

Usability was defined in different ways in different studies. One of the early definitions was "*usability is the quality of interaction which takes place*" (Bennet, 1979 as cited in Ryu, 2005). In 1991, Shackel (2009) generated some dimensions for usability, namely *effectiveness, learnability, flexibility and attitude* (pp. 342). He defined these dimensions by considering usability in the context of acceptance and focusing on the product perception. However, according to other researches, these definitions and dimensions were still ambiguous. In the same year, Bevan et al (1991) defined usability with three perspectives of measurements methods: "*the product-oriented view, the user-oriented view and the user performance view*."(pp. 1). Also, similar to Shackel (2009), he examined usability with regard to product acceptance perspective (Bevan et.al, 1991). In 1993, Nielson made a well-accepted categorization for usability as a HCI discipline member. Similar to Shackel (2009) and Bevan et al (1991), he defined usability as an effective factor for product acceptance. He generated some dimensions for usability: *learnability, efficiency, memorability, errors and satisfaction.* He was one of the first researchers who saw satisfaction as a dimension of usability. He defined satisfaction as a subjective assessment used in order to define how to influence users positively while using the system (Nielsen, 1993).

Although there is an increasing widespread recognition about usability, clear definitions are still needed. (Frokjaer et. al, 2000). Finally, International Organization for Standardization (ISO) determined a standard on usability (1998). According to ISO, usability includes three dimensions; *Effectiveness, Efficiency and Satisfaction*.
As described above, the definition of usability was shaped and evolved by various researchers in the areas of HCI and UCD. However, their definitions still share a few common constructs with regard to usability (Table 2.4).

Table 2.4 Dimensions in Early Usability Studies

Usability Dimensions	Shackel (1991)	Nielsen (1993)	ISO Part:9 (1998)
Effectiveness	*		*
Learnability	*	*	
Flexibility	*		
Attitude	*		
Errors		*	
Satisfaction		*	*
Memorability		*	
Efficiency			*

Usability is a major research area and well-defined concept for HCI literature (Han et al, 2001). HCI researchers investigated usability for mostly software products. Then, they began to be interested in computer related products. In HCI discipline, usability is measured mostly by objective performance-related dimensions, such as ease of learning, efficiency of use, memorability and errors rates although satisfaction is seen as a subjective part of usability (Jordan, 1998; Nielsen, 1993). According to Nielsen and Levy (1994), fewer studies were carried out on subjective part of usability, and satisfaction was mostly ignored because of traditional definition of usability in HCI discipline. Especially for consumer electronic products, it is needed to provide new subjective usability definitions. In addition, studies were done with regard to subjective side of usability, such as pleasure in use (Jordan (1998), beauty in use (Norman, 2004; Overbeeke & Wensveen, 2000; Overbeeke & Wensveen, 2004; Tractinsky, 2004; Hassenzahl, 2004), emotion in product design (Nagamachi, 1995) and image and impression as dimensions of usability for consumer electronic products (Kwahk & Han 2002; Han et al. 2000; Han et al. 2001; Han et al 2004; Han & Hong 2003; Yun et al. 2003; Han & Kim 2003; Han & Kim 2008).

2.3.1 Subjective Aspects of Usability

It is an accepted fact that usability is one of the major requirements for product development process and it has a significant impact on user product decision. During the years, researches have provided information to designers about usability with mostly objective measurement methods. Recently, researchers have recognized the importance of subjective part of usability, such as users' emotional responses and overall satisfaction and began to take it into consideration (Mugge & Schoormans, 2012; Trathen, 2000; Han et al, 2001). One of the accepted studies belongs to Han, Yun, Kwahk and Hong (2001). They brought a new approach to the usability of consumer electronic products. Consumer electronic products refer to products which have both hardware and software features, such as mobile phones. In this approach, researchers defined usability with two aspects: the performance and the image and impression as shown in Table 2.5. Like traditional usability concept, performance aspect is measured by objective metrics, such as task conformance, error prevention. Image and impression aspect refers to sense and feelings about product. It is measured by subjective metrics, such as satisfaction, acceptability. The aim of this approach is to satisfy the users in terms of both performance and image and impression dimensions (Kwahk & Han, 2002; Han & Kim, 2003; Han, 2001).

Table 2.5 Performance & Image/Impression Dimensions (Han et al, 2001)

Usability Dimensions	Performance & Image/Impression Dimensions
	Directness, Explicitness, Modelessness, Observability, Responsiveness, Simplicity
Learning / memorization	Consistency, Learnability, Memorability, Familiarity, Informativeness, Predictability,
	Controllability, Accessibility, Adaptability, Effectiveness, Effciency, Flexibility, Helpfulness, Multithreading, Task Conformance, Error Prevention, Recoverability
Basic Sense	Shape, Color, Balance, Texture, Translucency, Brightness, Heaviness, Volume
Description of Image	Elegance, Granularity, Dynamicity, Metaphoric Image, Harmoniousness, Luxuriousness, Magnificence, Neatness, Rigidty, Salience
Evaluative Feeling	Preference, Satisfaction, Acceptability, Comfort, Convenience, Reliability, Attractiveness

2.3.2 Subjective Measurement Methods of Usability

Usability issue has been investigated for a long time. As mentioned above, there are various usability dimensions that are the results of various studies. In addition, according to these dimensions, researchers have developed different methods in order to measure usability. There are three method categories known as inspection methods, testing methods and inquiry methods (Madan & Dubey, 2012; Avouris, 2001).

Boehm, Brown and Lipow developed Inspection method in 1976. It is based on experts' opinions and views on software interface. The aim of the methods is to define the problems of user interface design. The main methods are; *heuristic evaluation, heuristic estimation, cognitive walkthrough, pluralistic walkthrough, feature inspection, consistency inspection, standards inspection, formal usability inspection and a guidelines checklist* (Madan & Dubey, 2012; Avouris, 2001; Nielsen, 1994). Usability testing method measures system performance. Data is collected by objective metrics, such as error rates, task completion time. To collect data properly, well-defined tasks should be used in a testing laboratory. The commonly used methods for usability testing *are thinking aloud protocol, co-discovery, performance measurement and in-field studies*. The inquiry method is based on communication between user and evaluator with *focus groups, interviews, field observations, and questionnaires.* This method is mostly used for measuring user satisfaction (Avouris, 2001). User satisfaction is generally measured with Likert-scale questionnaire (Lewis, 1993) (Figure 2.19). As it is the main interest of this thesis, in the next section, definitions, dimensions and measurement methods of user satisfaction will be explained in detail.

Appendix. The IBM Questionnaires

The After-Scenario Questionnaire (ASQ)

Administration and Scoring. Give the questionnaire to a participant after he or she has completed a scenario during a usability evaluation. Average (with the arithmetic mean) the scores from the three items to obtain the ASQ score for a participant's satisfaction with the system for a given scenario. Low scores are better than high scores due to the anchors used in the 7-point scales. If a participant does not answer an item or marks N/A, average the remaining items to obtain the ASQ score.

Instructions and Items. The questionnaire's instructions and items are:

For each of the statements below, circle the rating of your choice.

1. Overall, I am satisfied with the ease of completing this task.

STRONGLY AGREE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**STRONGLY DISAGREE**

2. Overall, I am satisfied with the amount of time it took to complete this task.

STRONGLY AGREE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**STRONGLY DISAGREE**

3. Overall, I am satisfied with the support information (on-line help, messages, documentation) when completing this task.

STRONGLY AGREE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**STRONGLY DISAGREE**

Figure 2.19 Likert-scale Questionnaire Sample

2.4 User Satisfaction

In 1970s, manufacturers produced the products regardless of consumer’s preference. This type of production is called as the product-out strategy. Today, manufacturers follow market-in strategy, which focuses on consumer's desire and preference. Thus, consumers have options to buy the products with regard to their personal preferences. They can choose products that are suitable for their own design preferences, function and price (Nagamachi, 1995). Although they are free in buying what they desire among a wide variety of products, it is not easy to satisfy them. Because of different reasons, users tend to choose different products.

Formerly, users gave more importance to functions of products. Nowadays, users focus on not only functionality but also, aesthetics, emotion and pleasure. They began to consider both physical and psychological expectations while choosing products. Their satisfaction and preferences significantly influence the selection of products (Altas, 2006). Ryker et al (1997) claim that satisfaction has a great impact on user expectations related to computer systems. In this respect, usability is the dominant determinant for user expectations because satisfaction implies behavioral aspect of usability and it is more subjective than others such as efficiency and effectiveness (Han et al, 2001). Moreover, usability is a significant factor to satisfy the users because advancements in technology provide more functions and so, it has become more complex to use products (Altas, 2006).

Unlike the early studies, in the last decade, satisfaction is defined with new measures (Hornbæk, 2006). While traditional satisfaction includes *helpfulness, learnability and affect*; today, *aesthetics, expectations, luxuriousness, and comfort* imply the satisfaction (Yun et al, 2003; Han & Hong, 2003). However, limited systematic study was carried out on satisfaction. Therefore, each new research makes a significant contribution to satisfaction area (Hornbæk, 2006; Tractinsky, 2004).

As mentioned in the first chapter, first, disciplines of marketing and usability engineering and then, user centered design discipline began to study on satisfaction. While marketing discipline investigates the satisfaction as a consumer activity; usability engineering and UCD discipline focus on satisfaction as a subjective part of product usage (Altas, 2006). Early usability studies examined effectiveness and efficiency as an objective performance (Jordan, 1998; Han et al, 2000; Tractinsky et al, 2000; Sutcliffe, 2002; Lindgaard & Whitfield, 2004). It is thought that measuring objective performance is enough to evaluate the usability and researchers ignore satisfaction as a subjective part of usability. In that, usability has a restricted approach to satisfaction. But since 1990s, researchers began to give importance to user satisfaction as much as user performance. In other words, making products usable does not only mean increasing the task efficiency and decrease number of errors (Han et al, 2001; Han et al, 2000). Tractinsky et al (2000) claim that high performance and good qualities are not only major factors, but also product appearance and aesthetic factors are significant for satisfying users. In this context, new definitions of usability have been generated by different researchers (Kwahk &

Han, 2002; Han et al, 2001; Han et al, 2000). They claim that traditional usability is developed for software products and so, it is not suitable for consumer electronic products. In this respect, they re-organized dimensions for defining usability, such as image and impression.

Most importantly for our study, HCI discipline is interested in satisfaction (Dillon, 2001). To measure satisfaction, HCI literature uses scales (McNamara & Kirakowski, 2011). Also, usability engineering and UCD measure user satisfaction by using direct observations, questionnaires and interviews and think aloud protocol (Kanis, 1998). HCI discipline uses some questionnaires as QUIS, SUMI and QUEST. These questionnaires are mostly for web pages and performance oriented. Therefore, these tools are insufficient for consumer products in industrial design domain because different dimensions are expected to be dominant such as visual appeal, usefulness, usability, etc. Tractinsky et al (2000) argue that there can be other design features than usability which determines user satisfaction. In addition, Turhan & Kuru (2012) indicate that aesthetically pleasing products can affect user's behavior towards the usage of products positively. Therefore, they suggest that physical appearance should be taken into consideration in new product development processes.

2.4.1 Determinants of User Satisfaction

In the first section, the aim was to explain briefly the definition of satisfaction. Literature review will continue to focus on the determinants of user satisfaction. In addition, in this section, functionality, aesthetics, user experience, emotion and product design features will be analyzed as the determinants of user satisfaction.

Functionality is a technical term that defines the performance of a product. In that, functionality is an answer to question: "*what will the product do?*" (McNamara & Kirakowski, 2005). Functionality has long been studied in the HCI discipline. To measure the performance of products, researchers make objective measurement studies by evaluating error numbers, task completion time, accuracy, speed, task performance and error rates. Also, HCI discipline accepts product performance as a determinant of satisfaction for a long time. But, since 1990s, other issues such as experience, aesthetics and pleasure have been examined as the determinants (Heimler, 2003).

Chiang et al (2000) claim that poor functionality causes dissatisfaction. Users expect to fulfill the functions of product while using it. Therefore, designers create products to satisfy particular purpose or function. But, functionality is not the only factor used in satisfying users. *Aesthetics* is one of the significant determinants for user satisfaction (Lindgaard & Whitfield, 2004). In the beginning, HCI discipline was traditionally interested in only usability. But today, it focuses on the relationship between usability and aesthetics. It measures the perception of users regarding aesthetic value in order to satisfy users. In designing pleasurable products, both usability and aesthetics are instrumental (Tractinsky et al, 2000). HCI discipline investigated the effect of aesthetics on users and relationship between users and product (Ben-Bassat et al, 2006).

The recent interest in aesthetics exposes that there are other factors like pleasure that influence satisfaction. In addition, in the last decade, studies of fun, pleasure, and emotion in computer systems have attracted more attention of researchers (De-Angeli et al, 2006). Beside aesthetics, there is a growing interest in *user experience,* especially for HCI discipline. HCI discipline states that experience with a product generates *emotional consequences* on users, such as satisfaction, pleasure. User experience covers all sides of interaction between user and product. In addition, emotional reactions cannot be ignored (Hassenzahl, 2003). For a long time, usability was a major factor for satisfaction. But according to the recent studies, satisfaction has been a result of emotional behavior (Hassenzahl, 2004). In the last decade, HCI discipline has started to examine emotion as a satisfaction factor. Researchers state that emotion has a huge impact on user satisfaction (Agarwal & Meyer, 2009). They investigate how people feel during product usage. Are they frustrated or do they feel any pleasure? (Thüring & Mahlke, 2007). Using pleasurable products creates satisfaction on users. If users feel satisfied while using a product, they keep on using that product as long as possible (Jordan, 1998).

As mentioned above, researchers have begun to study on consumer electronic products in relation to user satisfaction. But it is not enough to apply same research tools for consumer electronic products because consumer electronic products are both functional and decorative ones. Therefore, Han et al (2000), Yun et al (2003), Han & Hong (2003) & Han et al (2004) began to carry out a research on applicable tool for usability of consumer electronic products. Researches show that *product design* features have a significant effect on user satisfaction. It was stated in these researches that usability included both the objective performance and subjective image/impression factors. The performance dimensions consist of three categories: perception/cognition, learning/memorization and control/action. Similarly, the image/impression dimensions cover basic sense, description of image and evaluative feeling/attitude. While objective dimensions measure performance of product and subjective image/impression dimensions define user satisfaction (Yun et al, 2003).

Similar to this approach, researchers began to develop new tools for evaluating user satisfaction with electronic consumer products. For example, McNamara & Kirakowski (2006) developed Consumer Products Questionnaire (CPQ). During the development of this questionnaire, they gathered some comments about electronic products from nearly 1000 users. They found that only 24 percent of the comments were related to usability; 47 percent of the comments addressed functionality, performance, hardware limitations, and durability; and 23 percent of comments were related to general experience with the device, including aesthetics, usefulness, concerns about health and safety, cost of using the device, and entertainment value (Kirakowski, 2006).

2.4.2 User Satisfaction Measurement Methods

Subjective side of usability attracts attention on user's emotional reactions, experience and opinions about a product or a system. As mentioned before, there are wide varieties of methods used for measuring subjective usability, such as inspection and inquiry methods. However, inquiry method is the main method used to measure subjective usability because it is benefitted from questionnaires and interviews which are based on users' comments as an evaluation tool (Ryu, 2005).

Usability Questionnaires

HCI researchers use questionnaires because they are quick and low cost evaluation tools used for collecting opinions, ideas, feelings and views of users (Ryu, 2005). Questionnaires have been used for a long time and so, there are wide varieties of categorization of questionnaire types. Sears & Jacko (2008) classify questionnaires mainly in two groups. Opinion surveys investigate general opinions of participants after a defined task conducted in controlled environment. The aim is to evaluate implemented procedure. Mostly, these types of surveys are used in HCI discipline to evaluate usability. Other type of survey is demographic survey. It collects information about age, sex, education and occupation of participants. All types of surveys use Likert scale and open ended questions (Sears & Jacko, 2008).

Several usability questionnaires were developed in HCI discipline such as Questionnaire for User Interaction Satisfaction (QUIS) (Chin et al., 1988), Software Usability Measurement Inventory (SUMI) (Kirakowski and Corbett, 1993), Post-Study System Usability Questionnaire (PSSUQ) (Lewis, 1995), System Usability Scale (SUS) (Brooke, 1996) and Purdue Usability Testing Questionnaire (PUTQ) (Lin et al., 1997). Also, there are End-User Computing Satisfaction Instrument (EUCSI) (Doll & Torkzadeh, 1988) and Technology Acceptance Model (TAM) (Davis, 1991), which cannot directly measure subjective usability. They are mainly interested in user acceptance issue. Thus, for this study, it is thought that it would be valuable to explain QUIS, SUMI, QUIS and PSSUQ.

Different dimensions were used in each usability questionnaire mentioned above in order to measure usability. QUIS directly investigates satisfaction issue (Chin et al., 1988). Also, SUMI (Kirakowski and Corbett, 1993) and PSSUQ (Lewis, 1995) measure satisfaction based on *"affect"* dimension that measures level of user's emotional responses. While SUMI focuses on the same dimensions like ISO standard, QUIS examines the dimensions to evaluate usability of software products (Ryu, 2005).

QUIS is developed by University of Maryland. It has five main items as: "Overall user reactions, Screen factors, Terminology and System Information, Learning Factors, System Capabilities", and 27 sub-items based on "Satisfaction, Feedback, Installation, Clarity of Presentation, Understandability and Learnability" dimensions. It has 7 updated versions. In the last version, "Technical Manuals and Online Help, Online Tutorials, Multimedia, Teleconferencing, and Software Installation" the main items were added to questionnaire. QUIS examines satisfaction by measuring overall user reactions that includes semantic differential items as "*Frustrating" vs. "Satisfying"*, *"Rigid" vs. "Flexible"* (Chin et al., 1988; Keinonen, 1997). QUIS is like a checklist for experts. Therefore, it can be difficult for users to evaluate the items and so, inadequate information can be obtained. QUIS is a scale for software products and it cannot be applied for other interactive products (Keinonen, 1997).

SUMI is a well-known questionnaire for software products and it was developed by University College Cork research group. It includes 50 items responded with "agree", "undecided", or "disagree", based on five dimensions: *Affect, Efficiency, Helpfulness, Control and Learnability*. SUMI is a small questionnaire and needs at least 10 participants. It is useful for comparing different kinds of software products (Kirakowski and Corbett, 1993; Keinonen, 1997).

PSSUQ is a part of three set of questionnaires used in different phases of usability. Lewis (1995) from IBM Corporation developed a set of questionnaires. Scenario Questionnaire is filled out to collect immediate user opinions after performing a task. Computer System Usability Questionnaire (CSUQ) measures general system usability (Keinonen, 1997). PSSUQ is a post study carried out with the aim of evaluating "System Usefulness, Information Quality, and Interface Quality" with 7 point Likert scale and 19 items based on specific tasks (Lewis, 2002). PSSUQ can be used for different types of products and for comparing different cultural groups.

As mentioned before, first usability studies were carried out by HCI discipline. Then, it skipped to other disciplines. Recently, product design discipline has begun to be interested in usability issue. In fact, this interest was developed with technological developments and so, researchers focused on consumer products, such as mobile phones. But, since consumer electronic products have both software and hardware features and existing subjective usability questionnaires focus on software products, researchers began to search new questionnaires. In addition, recently developed questionnaires are Mobile Phone Usability Questionnaire (MPUQ) (Ryu, 2005) and Consumer Product Questionnaire (CPQ) (McNamara, 2006). Also, before the development of MPUQ and CPQ, Demers, Weiss-Lambrou and Bernadette Ska (2002) developed Quebec User Evaluation of Satisfaction with assistive Technology (QUEST) for assistive technology devices (ATD) and Keinonen (1997) developed a questionnaire for heart rate monitors (HRM) (Ryu, 2005; Keinonen, 1997; Demers, 2002).

Keinonen examined usability dimensions for consumer products in his study (1998). He tried to analyze usability dimensions from perspective of consumer attitude formation. He developed a model related to expected usability that consists of consumer's beliefs and their emotional responses. He determined three dimensions as: *Interface Attributes, Interaction Attributes, and Emotional Attributes,* and seven sub-dimensions as: *Affect, Usefulness, Ease-of-Use, Functionality, Operational Logic and Qualities of Presentation* in order to evaluate usability (Figure 2.20). He created a questionnaire with these dimensions and applied this scale with 91 participants to analyze the usability of six different heart rate monitors. Keinonen's scale is one of the limited studies that focus on specific consumer products. Therefore, its usability dimensions and questionnaire items are useful sources for future studies (Keinonen, 1997a; Ryu, 2005).

Another study focusing on consumer products, QUEST was created in 1996. The purpose of this questionnaire is to measure the user satisfaction with assistive technology devices (ATD). Assistive technology produces assistive, adaptive, and rehabilitative devices for people with disabilities. QUEST is a questionnaire used for defining satisfaction as users' assessment of technological devices with respect to user's expectations, perceptions, attitudes and personal values. The construct of QUEST is based on general usability including satisfaction and performance dimensions. QUEST consists of two parts, *Device and Service* (Figure 2.21). Device is measured by comfort, weight, durability, adjustments, simplicity of use, dimensions, effectiveness and safety whereas service is measured by service delivery, repairs/servicing, follow-up services and professional services. QUEST categorizes all these dimensions with three groups, user, product and environment (Demers, 2002; Demers et al, 2000). This scale can be used in ATD device selection, use and evaluation (Demers et al, 2001).

Affect (AFF)

1 I would recommend this HRM to my exercise companions.
7 Training with this HRM is not satisfying.
13 Training with this HRM is mentally stimulating.
19 I would not like to use this HRM in every exercise.
25 Using this kind of HRM is frustrating.
31 This HRM is attractive.
37 This HRM is awkward.

Ease-of-use (EOU)

2 I find this HRM cumbersome to use.
8 Learning to operate this HRM is easy for me.
14 It is easy for me to remember how to perform tasks with this HRM.
20 Interacting with this HRM requires a lot of mental effort.
26 My interaction with this HRM is clear and understandable.
32 It takes a long time to learn to use this HRM.
38 Overall, I find this HRM easy to use.

Usefulness (USE)

3 Using this HRM would improve the quality of my exercise.
9 Using this HRM would give me greater control over my training.
15 This HRM enables me to achieve results more quickly.
21 This HRM supports critical aspects of my training.
27 Using this HRM improves my performance.
33 Using this HRM enhances my effectiveness on the training.
39 Overall, I find this HRM useful in my exercises.

Presentation (PRE)

4 Some of the labels or icons are too small.
16 The objects on the screen are labelled in an understandable way.
22 The buttons are situated in troublesome locations.
28 Characters on the screen are easy to read.
34 The buttons are labelled clearly and exactly.
40 This HRM applies obscure symbols and labels.

Logic (LOG)

5 The HRM has a simple and natural dialogue.
17 The HRM is not consistent.
23 All the operations can be carried out in a systematically similar way.
29 When using this HRM one has to make too many choices.
35 The logic of this HRM is obscure.
41 One needs only few pushes to complete tasks.

Functionality (FNC)

6 This HRM has features that would be necessary in products too.
12 One should be able to adjust parameters more accurately.
18 This HRM is suitable for many kinds of exercises.
30. This HRM provides very precise and comprehensive results.
36 This HRM is suitable only for the very basic tasks.
42 There are important features that lack from this HRM.

Figure 2.20 Keinonen’s Subjective Usability Questionnaire Dimensions and Items

1	2	3	4	5
not satisfied at all	not very satisfied	more or less satisfied	quite satisfied	very satisfied

ASSISTIVE DEVICE ***How satisfied are you with,***	
1. the **dimensions** (size, height, length, width) of your assistive device? *Comments*:	1 2 3 4 5
2. the **weight** of your assistive device? *Comments*:	1 2 3 4 5
3. the **ease in adjusting** (fixing, fastening) the parts of your assistive device? *Comments*:	1 2 3 4 5
4. how **safe and secure** your assistive device is? *Comments*:	1 2 3 4 5
5. the **durability** (endurance, resistance to wear) of your assistive device? *Comments*:	1 2 3 4 5
6. how **easy** it is to use your assistive device? *Comments*:	1 2 3 4 5
7. how **comfortable** your assistive device is? *Comments*:	1 2 3 4 5
8. how **effective** your assistive device is (the degree to which your device meets your needs)? *Comments*:	1 2 3 4 5

Figure 2.21 QUEST Scale Questions

MPUQ is developed by Ryu to evaluate subjective usability of electronic mobile products, such as mobile phones, smart phones, Personal Digital Assistants (PDAs), and Handheld Personal Computers (PCs) (2005). According to him, HCI discipline has studied usability for a long time and so, they have developed various questionnaires. But, Ryu (2005) states that these types of questionnaires like SUMI, QUIS and PSSUQ are appropriate for software products and not appropriate tools for mobile phones because mobile phones have both software and hardware features. Also, mobile phone has more subjective side than software products. Therefore, Ryu (2005) developed a questionnaire based on existing questionnaires. MPUQ includes

72 questions and six groups, *Learnability and ease of use (LEU), Helpfulness and problem solving capabilities (HPSC), Affective aspect and multimedia properties (AAMP), Commands and minimal memory load (CMML), Control and efficiency (CE) and Typical tasks for mobile phones (TTMP)*, based on wide variety of dimensions, such as satisfaction, affect, mental effort, frustration etc. (Table 2.7). It is a comprehensive questionnaire because it collects appropriate items for mobile products from existing questionnaires. In addition, it is the first questionnaire developed for these products.

Table 2.6 MPUQ Scale Questions

Factor Group	Item No.	Revised Question (structured to solicit "always-never" response)	Source of Items
Ease of Learning and Use (LEU)	1	Is it easy to learn to operate this product?	SUMI, PSSUQ, PUTQ, QUIS, QUEST, Keinonen (1998), Kwahk (1999)
	2	Is using this product sufficiently easy?	SUMI, QUIS
	3	Have the user needs regarding this product been sufficiently taken into consideration?	SUMI, PUTQ
	4	Is it relatively easy to move from one part of a task to another?	SUMI, Klockar et al.(2003)
	5	Can all operations be carried out in a systematically similar way?	SUMI, Keinonen (1998), Kwahk (1999)
	6	Are the operation of this product simple and uncomplicated?	PSSUQ, Keinonen (1998), QUEST, Kwahk (1999)
	7	Does this product enable the quick, effective, and economical performance of tasks?	PSSUQ, Keinonen (1998), Kwahk (1999)
	8	Is it easy to access the information that you need from the product?	PSSUQ, QUIS
	9	Is the organization of information on the product screen clear?	PSSUQ, QUIS
	10	Does product have all the functions and capabilities you expect it to have?	PSSUQ, Keinonen (1998)
	11	Are the color coding and data display compatible with familiar conventions?	PUTQ
	12	Is it easy for you to remember how to perform tasks with this product?	QUIS, Keinonen (1998), Kwahk (1999)
	13	Is the interface with this product clear and underatandable?	PUTQ, QUIS, Keinonen (1998)

Finally, CPQ was developed to measure the user-satisfaction with electronic consumer products (ECPs). It consists of four factors, *Efficiency, Helpfulness, Transparency and Appearance* and 34 items (Table 2.7). The aim of this scale is to measure the satisfaction of wide range of products because other questionnaires are mainly developed for specific products but CPQ can be applied for everyday products with embedded technology. Another aim of CPQ is to focus on user satisfaction rather than full usability evaluation because the number of studies carried out on satisfaction is insufficient and each study constitutes new information about satisfaction (McNamara & Kirakowski, 2011).

Table 2.7 CPQ Scale Dimensions and Items

Consumer Products Questionnaire	
Appearance	
App1	I like the look of this product
App2	This product is always going to look out of place
App3	I enjoy using this product
App4	The size of the product is just right
Efficiency	
Eff1	It is possible to become familiar with this product after a short length of time
Eff2	It is easy to make this product do exactly what I want
Eff3	The features offered by this product are easy to identify
Eff4	I rarely make mistakes when using this product
Eff5	I found it easy to become familiar with this product
Eff6	I feel at ease using this product
Eff7	I often forget how to work this product
Helpfulness	
Help1	This product helps me to solve any problem I encounter while using it
Help2	This product helps me fix the problem if it goes wrong

These four questionnaires, CPQ, MPUQ, QUEST and Keinonen's scale, were developed for specific products. Therefore, when it is focused on the subject of this thesis with respect to non-keyboard input devices, these questionnaires are not most appropriate tools to evaluate them. More suitable one was investigated in different literatures apart from HCI and product design disciplines.

Woods, Hastings, Buckle & Haslam (2002) prepared a study for Health and Safety Executive (HSE), an organization interested in workplace health, safety and welfare in United Kingdom. This study is based on five empirical researches that investigate health problems related to use of NKIDs. As the result of their researches, they generated a questionnaire based on device operation, device performance, device design and device comfort and 58 items were used to assess 8 different types of NKID with expert users (Appendix C). This questionnaire is based on ISO's usability questionnaire (1998). Similar to ISO (1998), Woods et al (2002) assessed NKIDs with satisfaction, operation and comfort dimensions. Also, they collected subjective comments of users to expose the new criteria for evaluating NKIDs. Although this questionnaire has been developed as a result of a study made for a health organization, it can be used to assess NKIDs for different research studies like this thesis because although this questionnaire is not for military products, common part of this questionnaire and this thesis is NKIDs and also, the study of Woods and his colleagues includes detailed questions.

The detailed information about how this questionnaire is applied on this thesis and the structure of research study will be given in the Methodology Chapter.

CHAPTER 3

METHODOLOGY

In this chapter the research study is presented in terms of its aim, details of the methodology and the results.

The chapter starts with the explanation of the methodology which consists of two parts. Following sections explain the details of these parts; preliminary and the main studies including the overall design of the study, and its conduct and data analysis procedures. Lastly, the chapter is concluded with the results of the study.

3.1 Aim of the Research Study

As seen in the literature review study, it is observed that user satisfaction has been examined in different perspectives. However, there are limited number of field studies in which NKIDs are assessed in terms of user satisfaction from military operators' perspectives. In addition, there are no sufficient reliable indicators to guide designers' decisions which would satisfy users in military operations. It is also seen in the literature that user satisfaction has a strong effect on performance and the performance is an important factor that affecting the success of missions in military. Therefore, it is aimed in this study to examine the factors that have influence on user satisfaction with regard to NKIDs in military. Also, the research study is specifically carried out to develop general and device specific recommendations for the device design and the device selection process. In this context, following questions are proposed for the research study.

- What are the design criteria for NKIDs in military with regard to user satisfaction?

- Which factors are significant for the usage of NKIDs in military concerning user satisfaction?

- Which NKIDs are preferred in terms of platforms of Air, Navy and Land?

In order to find the answers of these questions, related scales, models and questionnaire were examined. In the light of the scanned literature, it was realized that the questionnaire study of Woods, Hastings, Buckle and Haslam (2002) was found to be more suitable for this research study. It is worth to mention an important issue at this point that, as the main purpose of this study was not to prove the validity of any scale and model or create an alternative satisfaction model for the military, the questionnaire of Woods and his colleagues (2002) was selected to be used for this thesis based on the results of preliminary study and scanned literature review.

The research study consists of two main parts, namely a preliminary and a main study. Both of them were conducted in Turkish which is the native language of all the participants. Their translations in English can be seen in Appendix A and C. The research study structure is presented in detail in Figure 3.1.

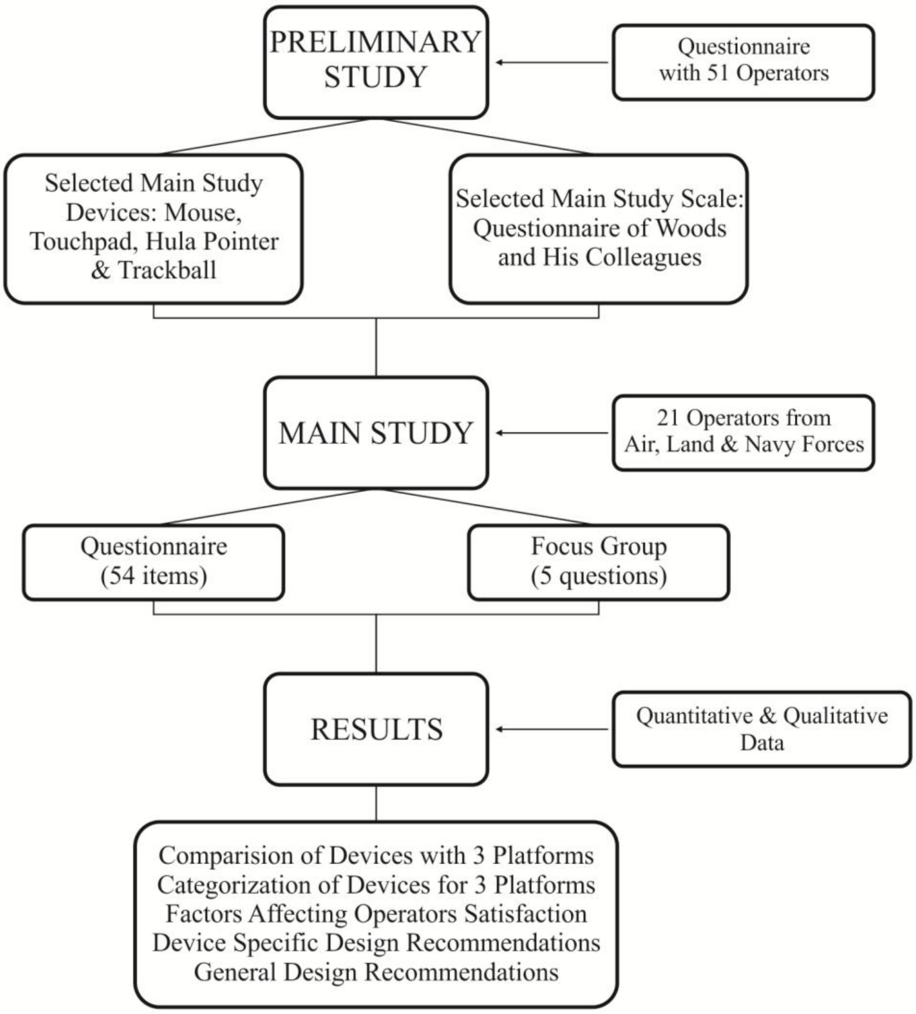

Figure 3.1 Research Study Structure

3.2 Preliminary Study

The purpose of the preliminary study was to decide on the product samples which would be used in the main study and collect keywords to understand the reasons of the participants' NKID selection to design the questionnaire of the main study. In the light of this study, the main study was developed based on the findings of the preliminary study.

3.2.1 Design of the Preliminary Study

The questionnaire includes only two questions: one 5 point Likert-scale question and an open ended question. At first, the participants were asked to rate the devices on the scale by using scores from 1 to 5. “1” refers to “strongly dissatisfy” and “5” refers to “strongly satisfy”. “Never used” option was added to the scale in order to determine the participants who have no experience with shown devices. Then, an open ended question was asked to gather information about their reasons while they were rating the devices regarding their satisfaction (Appendix A).

3.2.2 The Conduct of the Preliminary Study

The questionnaire was conducted with 51 operators from three different Turkish Military Forces; namely, Land, Navy and Air. The study was performed by sending e-mails to 44 operators who work in different garrisons, namely Mamak and Etimesgut in Ankara, Gölcük-Kocaeli, Kayseri, Eskişehir and Batman. Seven operators from Navy Forces filled out the questionnaire under the observation of the author. Filling the questionnaire took approximately 10 minutes.

3.2.2.1 Profile of the Participants

The preliminary study was performed with 51 military operators. There were 17 operators from each of three Forces. All of them were men and their ages range was from 20 to 49 (avg. 29, 8).

The opinions of participants were important with respect to assess the usage of NKIDs and the success of their future implementations because the profession of the participants required active usage of these devices.

3.2.2.2 Product Samples

As mentioned before, the questionnaire was designed to search for the devices which military operators preferred the most and the least. In this context; eight device types were selected based on the results of the literature review. Images of these devices were used representatively as shown in Figure 3.2.

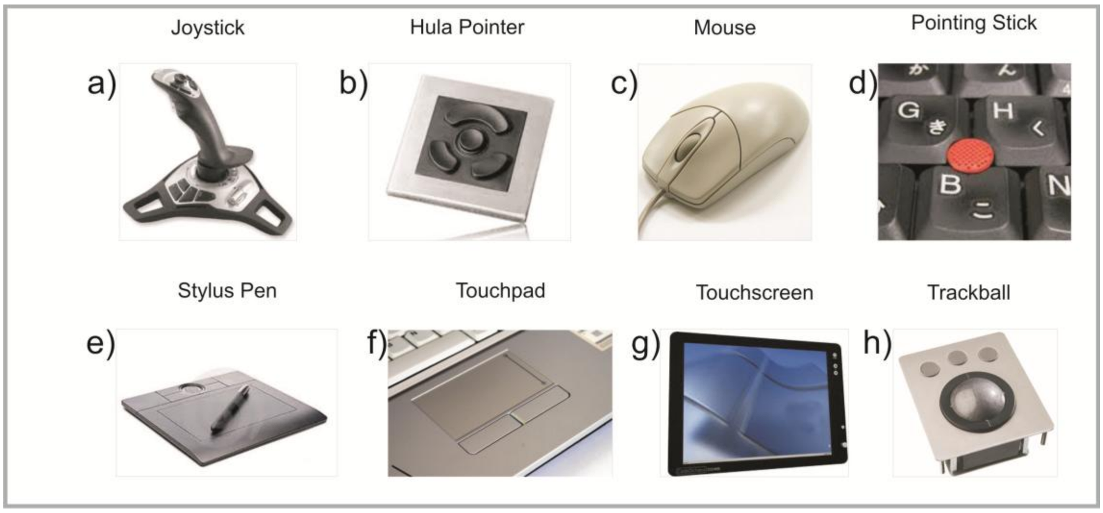

Figure 3.2 Device Samples (b & h retrieved from https://www ikey.com, a, c & d http://www.nsi-be.com, e, f & g http://www.notebookcheck.net)

3.2.3 Data Analysis Procedure

The data gathered by the preliminary study were analyzed with SPSS v15. To analyze the extent to which devices was spread around, their averages, descriptive statistics including mean values and frequency tables were produced. Related figures and tables were visualized by Microsoft Excel 2010. In order to analyze the data gathered with the open-ended question, responses of the participants were coded thematically (Appendix D and E).

3.2.4 Results of the Preliminary Study

Thus, with the preliminary study, both quantitative and qualitative data were gathered.

Firstly, mean values and frequency ratings were calculated and it was observed that mouse and trackball were preferred as the most satisfactory devices and hula pointer and touchpad were stated as the least preferred ones. Secondly, the answers of open ended question were thematically coded and categorized in relation to the findings of the literature review study. The results were compared with the related studies, models and scales, such as the questionnaires explained in the literature review.

As a result of the preliminary study, mouse, trackball, touchpad and hula pointer were chosen as the study materials for the main study and it was realized that statements in the questionnaire of Woods et al. had many similarities with the statements of the participants for open-ended question, as it will be explained in detail in the following sections.

3.2.4.1 Results of the Questionnaire

The number of participants who rated the devices based on their experiences can be seen in Figure 3.3. As seen in the Figure 3.3, most of the participants have used joystick (%98), mouse (%94), touchpad (%86), pointing stick (%96) and trackball (%98) before.

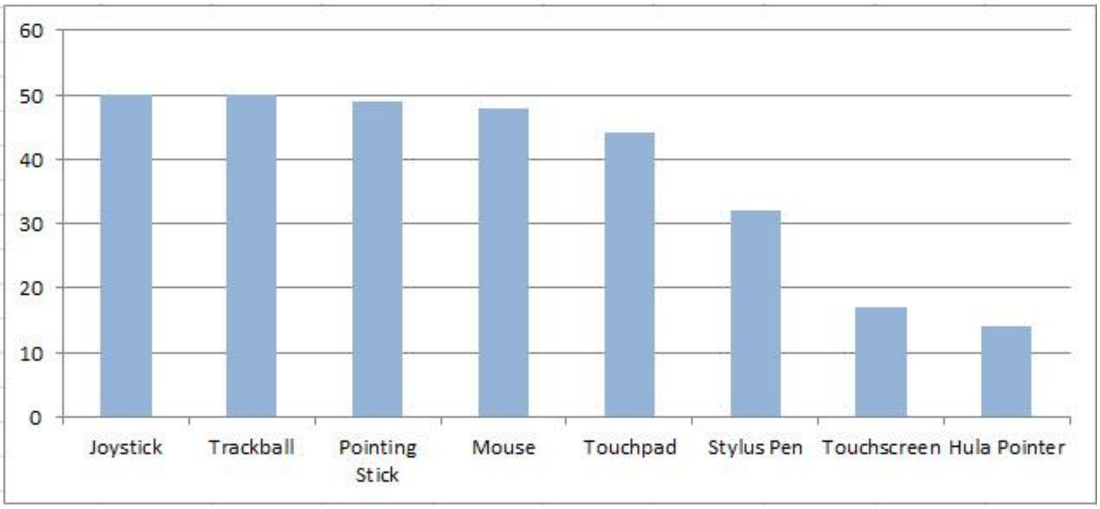

Figure 3.3 The Number of Participants who Experienced Product Samples Before

Mean values and standard deviations of the scores of each device were calculated for the assessment. Mean values represent the averages of scores given to the devices in the questionnaire and standard deviations show how much variation or dispersion from the average exists. Low standard deviation indicates that the data points tend to be very close to the mean; a high standard deviation indicates that the data points are spread out over a large range of values.

The results given in Figure 3.4 show that most of the operators are satisfied with mouse and trackball. In the contrary, the least satisfactory devices are touchpad and hula pointer. However, it can be understood from the results that mouse, touch screen, trackball and touchpad have more continuous rating distributions within smaller standard deviations while pointing stick, stylus pen, hula pointer and joystick have discrete distributions with higher standard deviations. This means that participants did not give consistent grades to these devices (Table 3.1).

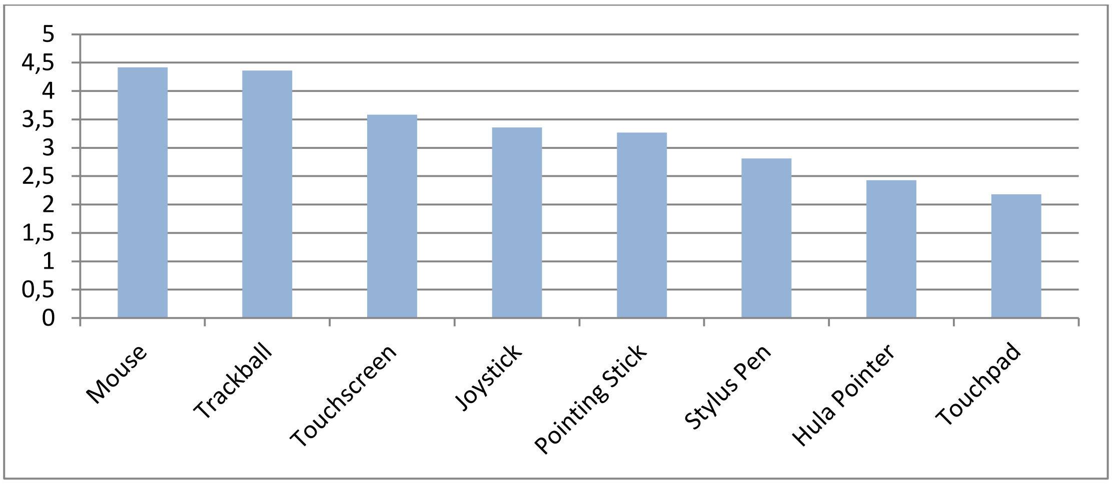

Figure 3.4 Mean Values for NKIDs with 51 Operators

Table 3.1 Standard Deviations for NKIDs

	Joystick	Hula Pointer	Stylus Pen	Pointing Stick	Touchpad	Trackball	Touchscreen	Mouse
Standard Deviation	1,3	1,28	1,25	1,15	1,06	0,98	0,87	0,7

In order to make the right decision about the choice of the product samples, detailed analyses were performed. The data were analyzed according to the platforms of the participants. According to the results given in Figure 3.5, there are no significant differences in mean values between Land, Navy and Air forces which mean that operators working in different platforms have similar preferences in terms of product samples.

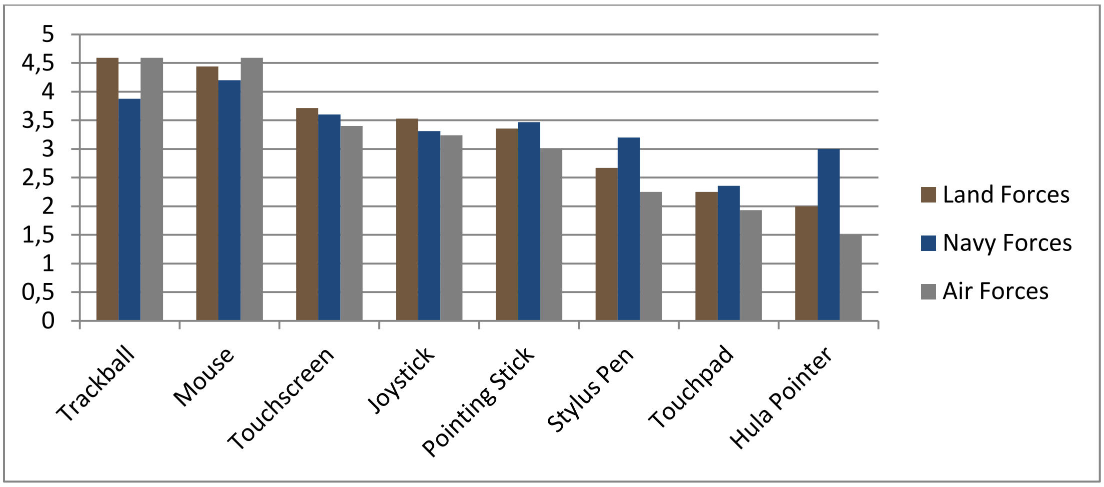

Figure 3.5 Mean Values for NKIDs in relation to Platforms

The data were also examined by concerning the frequency of Likert-scale items. According to the results, in Figure 3.6, mouse (%72) and trackball (%74) get highest ratings in the answers of "satisfied" and "very satisfied". In contrast, hula pointer (%6) and touchpad (%12) get lowest scores in the answers of "satisfied" and "very satisfied". With this analysis, it is proven that in the main study, mouse and trackball can be used as the most satisfactory; hula pointer and touchpad can be used as the least satisfactory devices.

Figure 3.6 Frequencies of Likert Scale Items for NKIDs

3.2.4.2 Results of the Open-Ended Question

In the second part of the preliminary study, the operators were asked to mention the reasons and influential factors while they rated the devices regarding their satisfaction. The participants explained their reasons shortly by using keywords such as "…devices were rated according to durability, maintenance, being fast and being simple..." or while one participant claimed that "Performance and comfort were important factor”, another one stated that “Easy usage, being practical and giving high speed responses were influential factors.”

In the data analyses, related keywords were categorized. The groups of these keywords can be seen in Table 3.2. Original version of the statements in Turkish can be seen in the Appendix E.

Table 3.2 Categorization of Keywords Mentioned in the Preliminary Study

Performance of device	**Operation of device**	**Design of device**	**Comfort of device**	**Others**
response time	easy usage	device design	comfort	durability
practical	basic	no slipping	no hand fatigue	flexibility
performance	ease of use	reaching buttons	grip comfort	impermeability
sensitivity	low effort to operate		low effort	
high speed response				

In the light of the scanned literature and according to the keywords gathered in the preliminary study, following results were obtained:

- Mouse, trackball, touchpad and hula pointer were selected as the product samples for the main study.

- The comments of the participants included very similar satisfaction measurement items with the questionnaire items of Woods and his colleagues. In addition, questionnaire of Woods et al. (2002) was comprehensive enough for the main study.

3.3 Main Study

The main study consists of a questionnaire study and a focus group discussion, which were preferred instead of individual in-depth interviews due to the time constraints of military operators.

3.3.1 Design of the Main Study

As mentioned before, the aim of the main study was to get information about the participants' opinions on their satisfaction towards selected products. Hence, the questionnaire of Woods et al. (2002) was selected as the most convenient one within the related literature regarding the results of the preliminary study. Additionally, a set of open-ended questions were prepared for the focus group discussion.

3.3.1.1 Representative Tasks for the Main Study

As in the study of Woods et al. (2002), in the main study, three representative tasks were prepared to assess the devices with major functions, such as clicking, dragging, cutting, pasting, highlighting and scrolling, which are elemental functions defined in the related literature. Although it could be better to use real tasks while measuring user satisfaction, representative tasks were preferred to be used in the study because of the military security restrictions.

- In the first task, the participants were asked to perform clicking and scrolling.
- In the second task, the participants tried to frame sentences with unordered words by cutting, pasting and highlighting.
- In the final task, the participants selected some shapes and drag them into different positions.

During the study, all of the participants from different platforms were asked to do the same tasks in the same order in order to get accurate results.

3.3.1.2 Structure of the Questionnaire Study

The questionnaire in the study of Woods and his colleagues is composed of three parts. First part includes questions about the demographic information of the participants. In the second part, there are 54 questions about the devices in four categories; *device performance, device operation, device design and device comfort* (Appendix B). The details about these categories can be explained as;

Device Performance: This category includes measurement items in relation to speed, accuracy, sensitivity and controllability of devices. Also, other related items were ordered to compare the performance of devices as *"Feedback provided for button actuation"* and *"Operates in same manner for similar tasks"*.

Device Operation: This factor analyzed the usefulness and usage of the devices. It includes items as *"Low effort required operating"* and *"Cables do not interfere with movement"*.

Device Design: This category includes items such as grip surface, shape of buttons, size and weight of devices to examine the design of the devices. Also, it contains the items such as *"Design makes me feel positive towards use"* and *"Device design enhances its operation"*.

Device Comfort: This category includes items such as *"Used without deviations of arm"* and *"No finger fatigue"* to examine comfort of the participants while using the devices.

Because of its targeted subject area, the questionnaire of Woods et al. (2002) was not fully applicable for this study and it required some modifications in order to provide compatibility.

3.3.1.3 Revision of the Questionnaire

As mentioned before, the questionnaire of Woods and his colleagues was not sufficient for this study. Therefore, following steps were performed.

- Three pilot studies were conducted with three military console operators from three different platforms, *Land, Navy and Air Forces* and it was realized that existing questionnaire items were insufficient to get the participants' general perception about these devices. Hence, four questions about general operation, general comfort, general satisfaction and applicability of product samples to different platforms were added to the end of the questionnaire as the final part.

- With the pilot studies, it was realized that there were repetitious questionnaire items. Hence, correlation analysis was made in order to revise and confirm the questionnaire. Correlation analysis examines the direction and intensity of the relationship between two or more different variables. But, this correlation is not an indication of cause-effect relationships. In the analysis, Pearson correlation takes a value between 1 and -1. Negative and positive marks represent direction of the relationship and the value determines the degree of magnitude of the coefficient. Negative values show that while a variable increases, other one decreases. Positive values show that both variables increase or decrease together (Eymen, 2007) (Table 3.3).

Table 3.3 Example of Correlation Analysis Result

		Q1	Q2	Q3	Q4	Q5
Q1	Pearson Correlation	1	,894(**)	,927(**)	,881(**)	,897(**)
	Sig. (2-tailed)	0,000	0,000	0,000	0,000	0,000
	N	84	84	84	84	84
Q2	Pearson Correlation	,894(**)	1	,891(**)	,822(**)	,859(**)
	Sig. (2-tailed)	0,000	0,000	0,000	0,000	0,000
	N	84	84	84	84	84
Q3	Pearson Correlation	,927(**)	,891(**)	1	,909(**)	,949(**)
	Sig. (2-tailed)	0,000	0,000	0,000	0,000	0,000
	N	84	84	84	84	84

When the data were analyzed, the following results were obtained (Appendix F).

- There are strong and positive relationships between the questions from 1 to 16 related to *Device Performance*, 17 to 25 related to *Device Operation*, 26 to 42 related to Device Design and 43 to 54 related to Device Comfort. These results confirmed the categorization of Woods et al. (2002) questionnaire.

- The results show that the question 24 has weak relationships with the questions from 17 to 25. Therefore, question 24 was omitted (Table 3.4).

- As mentioned before, there were three questions about sensitivity, *the question 4, 9 and 16*, but the results show that their relationships are not strong. This means that the participants gave different answers to these questions. It can be said that they did not recognized that these questions belongs to the same subject or the questions were misunderstood because according to the results, the questions 9 and 16 also have weak relationships with the questions from 1 to 16 (Table 3.5). Therefore, these questions were omitted.

Table 3.4 Result of Correlation Analysis for the Question 24

Device Operation Items		Q24-"Cables do not interfere with movement"
Q17	Pearson Correlation	,708(**)
	Sig. (2-tailed)	0,000
	N	84
Q18	Pearson Correlation	,773(**)
	Sig. (2-tailed)	0,000
	N	84
Q19	Pearson Correlation	,621(**)
	Sig. (2-tailed)	0,000
	N	84
Q20	Pearson Correlation	,622(**)
	Sig. (2-tailed)	0,000
	N	84
Q21	Pearson Correlation	,480(**)
	Sig. (2-tailed)	0,000
	N	84
Q22	Pearson Correlation	,690(**)
	Sig. (2-tailed)	0,000
	N	84
Q23	Pearson Correlation	,637(**)
	Sig. (2-tailed)	0,000
	N	84
Q24	Pearson Correlation	1
	Sig. (2-tailed)	0,000
	N	84
Q25	Pearson Correlation	,763(**)
	Sig. (2-tailed)	0,000
	N	84

Table 3.5 Results of Correlation Analysis for the Questions 4, 9 and 16

Device Performance Items		Q4-"Precision adequate"	Q9-"Not too Sensitive"	Q16-"Accurate"
Q1	Pearson Correlation	,881(**)	,739(**)	,668(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q2	Pearson Correlation	,822(**)	,676(**)	,577(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q3	Pearson Correlation	,909(**)	,745(**)	,681(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q4	Pearson Correlation	1	,745(**)	,728(**)
	Sig. (2-tailed)		0,000	0,000
	N	84	84	84
Q5	Pearson Correlation	,902(**)	,767(**)	,752(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q6	Pearson Correlation	,869(**)	,736(**)	,703(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q7	Pearson Correlation	,868(**)	,660(**)	,681(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q8	Pearson Correlation	,757(**)	,735(**)	,570(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q9	Pearson Correlation	,745(**)	1	,606(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q10	Pearson Correlation	,868(**)	,758(**)	,710(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q11	Pearson Correlation	,843(**)	,714(**)	,708(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q12	Pearson Correlation	,848(**)	,717(**)	,708(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q13	Pearson Correlation	,790(**)	,656(**)	,646(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q14	Pearson Correlation	,791(**)	,654(**)	,605(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q15	Pearson Correlation	,813(**)	,672(**)	,785(**)
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84
Q16	Pearson Correlation	,728(**)	,606(**)	1
	Sig. (2-tailed)	0,000	0,000	0,000
	N	84	84	84

With the help of the pilot studies and correlation analysis, significant four questions were added, irrelevant and repetitious items were omitted and the similar questionnaire items were grouped in relation to intensity of the relationship between the questions.

The results of the main study will be given under these categorizations in the next section.

3.3.1.4 Structure of the Focus Group Discussion

The aim of the questionnaire session was to obtain the participants' subjective preferences about product samples. But, the focus group discussion aims to obtain perceptions and in-depth motivations of the participants on the defined area. Also, the help of this method it can be gathered both individual and interactive opinions of the participants (Krueger & Casey, 2009).

A focus group discussion was performed as one of the in-depth interviewing methods to encourage discussion and the expression of different opinions. As mentioned before, because of the military operators' time constraint and to get their both individual and interactive opinions, focus group was chosen instead of individual interviews. It was aimed to get direct opinions of the participants regarding their satisfaction about the NKIDs. Focus group discussions were performed with the same participants just after the questionnaire study was conducted.

The questions of the discussion were open-ended and predetermined such as:

- What are your general opinions about these devices?
- Which properties of the devices are important? Which properties a device should have?
- Which devices are you satisfied or dissatisfied with? Why?
- Do you encounter with a problem while using? What kind of problems?

- Do you have you any suggestions and preferences in relation to design of these devices?

3.3.2 The Conduct of the Main Study

The study was performed by visiting three different military garrisons in three different cities in Turkey. Management of the organization for each garrison was made two days earlier before the meeting date.

3.3.2.1 Profile of the Participants

When compared with the civilian contexts, it was difficult to find a large number of operators and meet them face to face because of limited military population related with the thesis' subject and military security restrictions. Therefore, the main study was performed by only 21 military operators from Turkish Navy, Land and Air Forces, which were experienced users of mouse, touchpad, trackball and hula pointer.

The operators had different work definitions such as link operator, air operator, COMINT operator and ELINT operator, which were categorized under Electronic Warfare Operators (16), and also, there were Radar Operators (5). Their ages were between 20 and 49. Moreover, 18 out of 21 participants used their right hands and more than 50% of operators were on mission between 2-6 hours.

3.3.2.2 Product Samples

As mentioned before, as a result of the preliminary study, mouse and trackball were chosen as the most satisfactory devices and touchpad and hula pointer were chosen as the least ones. But, there were wide varieties of these devices. Therefore, the devices, which have been in use in ASELSAN, were examined and the most widely used models of these devices were selected to be used in the main study as shown in Figure 3.7.

During the research study, mouse, touchpad, hula pointer and trackball were performed respectively by all participants. All devices were performed with the same order in each study in order to make an accurate comparison.

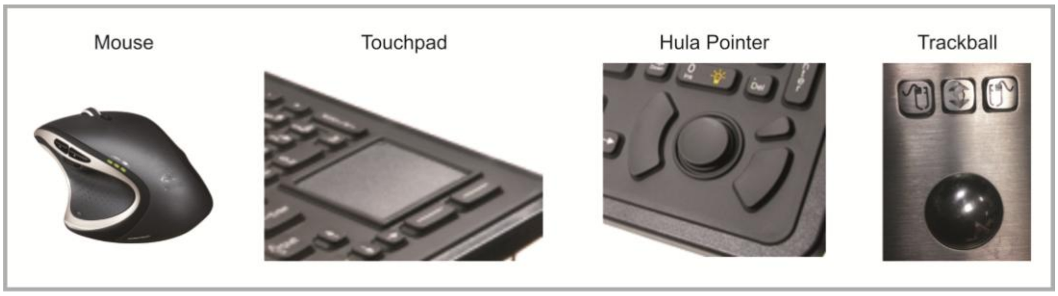

Figure 3.7 Product Samples Selected for the Main Study

3.3.2.3 Environment

As mentioned before, the author works as a designer in ASELSAN. The company has three entry permits based on related projects for three different garrisons that include operators. Therefore, 21 operators were selected from these garrisons and each seven operators from each garrison were selected according to their duty and training schedule by their commanders.

First, in Kocaeli, seven operators from Navy Forces performed the study. The meeting room was small and there was no sun light. There was a round table with eight chairs as show in Figure 3.8a. Second meeting was performed with seven operators working in Land Forces in Ankara and finally, seven operators of Air Forces performed the study in Kayseri.

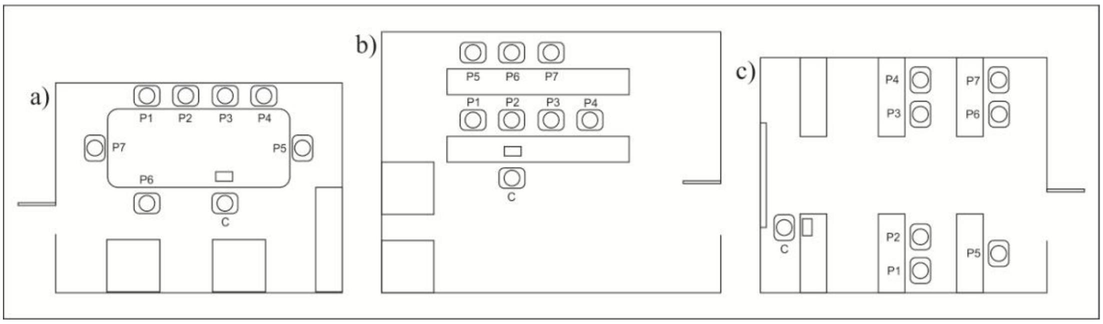

Figure 3.8 Layouts of the Main Study Environment in Focus Group Discussion Session; a) Navy Forces, b) Land Forces c) Air Forces *(P: participant & C: conductor)*

3.3.2.4 Procedure

At the beginning of each meeting, seven operators were informed about the study. Then, they performed three defined tasks by four devices one by one with the same order. After the tasks were completed, the participants filled out the questionnaire in order to assess the devices. At the end of questionnaire session, all operators came together in the meeting room; focus group discussion was made to obtain their subjective evaluations regarding the devices. During the discussion, the author noted down the statements since the audio-visual data recording was not allowed.

Questionnaire study and focus group discussion took approximately 45-50 minutes in total. The procedure of the study was performed in the same manner for all platforms.

3.3.3 Data Analysis Procedure

Data analysis procedure included two parts based on the findings of the questionnaire and focus group sessions.

Statistical Analyses

Statistical analyses were used to evaluate the data collected in the questionnaire with the help of SPSS v.15. The aim was to define general views of the participants and understand the relationship between devices and their satisfaction by comparing the devices.

First, as mentioned before, the questionnaire was revised by using Correlation analysis with the following aims.

- To confirm the categorization of the questions in the questionnaire of Woods et al (2002).
- To reveal the degree and direction of relationships between the questions.
- To show which questions are relatively close to each other and which were apart.
- To determine if there are repetitions and unsuitable questions.

Following this, the overall grades of 21 participants for four devices were analyzed by using descriptive tables, including frequency and cross tables. This provided revealing general views of the participants about the devices. Then, one –way ANOVA (Analysis of Variance) was used to show the statistically significant differences between the devices and between the platforms. That is, this analysis examines if the platforms of the participants and differences of the devices affect the responses of the participants (Eymen, 2007). The statistical significance was taken *0.05* as base. These data were visualized by Microsoft Excel.

Thematic Coding

Following statistical analyses, in order to evaluate the participants' accounts in the focus group discussion, thematic coding was used for organizing the data to identify the patterns and themes and find common opinions and evaluations of the discussion to be transcribed. Then, some similar patterns, themes and thoughts were grouped thematically under the previously stated categories in the questionnaire. They were counted and their causal relationships were captured to compare with the results of the quantitative study (Table 3.6).

Table 3.6 Examples of Data Analysis Procedure

Categorization of Participants' Statements		
Statements by Participants	Related Product Property	Related Factor
Mouse gives feedback quickly.	feedback	performance
Sometimes, we can accidentally press all the buttons at the same time.	buttons size and location	design

3.3.4 Results of the Main Study

In the main study, both quantitative and qualitative data were gathered. Quantitative data were analyzed statistically and qualitative data were analyzed with the method of thematic coding. The results will be examined in the next sections.

3.3.4.1 Results of the Questionnaire Session

As mentioned before, the questionnaire consists of three parts. First part is related to demographic information about the participants. Second part includes 54 questionnaire items under the four measures to assess the devices. These were *device performance device operation, device design and device comfort.* To compare the devices, mean values were produced and to find out the statistical differences, values of significance between the devices and between the platforms were examined (Appendix G).

Device Performance

The mean scores with items regarding the performance of the devices can be seen in Table 3.7.

Table 3.7 The Mean Scores with Items in relation to Performance of the Devices

Devices	mouse		touchpad		hula pointer		trackball	
Performance Items	mean	sd	mean	sd	mean	sd	mean	sd
Q1-Responds as would expect	4,33	0,73	3,14	1,31	2,61	1,02	3,57	1,27
Q2-Operates in same manner for similar tasks	4,09	1,04	3,14	1,27	2,47	1,03	3,57	1,30
Q3-Adequate feedback	4,14	0,79	3,23	1,26	2,42	0,97	3,57	1,26
Q4-Precision adequate	4,04	1,07	3,09	1,33	2,14	1,06	3,66	1,39
Q5-Responsiveness satisfactory	4,28	0,64	3,00	1,34	2,23	1,09	3,57	1,36
Q6-Adequate control	4,14	1,06	2,9	1,51	2,09	1,17	3,47	1,47
Q7-Allows precision task to be conducted	3,76	1,30	2,85	1,45	2,33	1,15	3,57	1,43
Q8-Feedback provided for button actuation	3,66	1,34	3,00	1,34	2,23	1,13	3,52	1,32
Q10-Right level of control	4,14	0,79	2,90	1,33	2,23	1,09	3,57	1,43
Q11-Easy to select information on screen	4,42	0,59	2,80	1,32	2,19	1,03	3,66	1,39
Q12-Easy to place pointer	4,23	0,99	2,66	1,27	2,23	1,13	3,52	1,36
Q13-Easy to move pointer around screen	4,28	0,95	2,85	1,35	2,42	1,2	3,47	1,36
Q14-Comfortable level of force for actuation	4,28	0,84	3,00	1,44	2,71	1,27	3,52	1,36
Q15-Smooth movement	4,19	0,87	2,85	1,45	2,33	1,11	3,52	1,43

The results show that,

- Mainly, mouse gets the highest mean values and lowest standard deviation scores for all performance questions.
- Mouse gets the highest mean score (4,33) with regard to respond/meet the participants’ expectations.
- Only hula pointer operates in the same manner for similar tasks with lower mean value (2,47). In contrast, it gets the lowest standard deviation score (1,03).

- Hula pointer gets the lowest mean values (2,14 & 2,09) with regard to sensitivity and controlling. In contrast, according to the participants, mouse and trackball have high sensitivity and can be controlled more easily.
- Hula pointer does not respond as satisfactorily as mouse, trackball and touchpad.
- Mean values of mouse and trackball are between 3 and 4 with regard to allow precision tasks to be conducted. In contrast, touchpad and hula pointer have mean values between 2 and 3, but hula pointer gets the lowest standard deviation score (1,15).
- Mouse, touchpad and trackball provide feedback for button actuation with the mean values between 3 and 4. In contrast, hula pointer has the lowest standard deviation score (1,13).
- Mouse and trackball get high mean values in relation to easy to select, move and place the pointer easily.
- Mouse, touchpad and trackball require having comfortable level of force for actuation with the mean values more than 3.

Device Operation

The mean scores with items in relation to operation of the devices can be seen in Table 3.8.

Table 3.8 The Mean Scores with Items in relation to Operation of the Devices

Devices	mouse		touchpad		hula pointer		trackball	
Operation Items	Mean	sd	mean	sd	mean	sd	mean	sd
Q17-Obvious how to operate device	4,38	0,58	3,28	1,27	3,04	1,2	3,57	1,24
Q18-Easy to discover how to operate	4,42	0,59	3,38	1,28	3,42	1,16	3,47	1,28
Q19-Easy to use	4,47	0,60	3,14	1,35	2,80	1,28	3,47	1,40
Q20-Did not make mistakes	4,19	0,98	3,04	1,24	2,71	1,14	3,47	1,36
Q21-Acceptable operation speed	4,38	0,80	3,09	1,3	2,38	1,11	3,57	1,39
Q22-Not complicated to use	4,52	0,60	3,38	1,32	3,00	1,18	3,52	1,32
Q23-Low effort required to operate	4,38	0,74	3,19	1,32	2,85	1,35	3,47	1,32
Q25-Adequate interaction between hard and software	4,00	1,00	3,38	1,32	3,14	1,15	3,47	1,24

The results show that,

- Mainly, mouse gets the highest mean values and lowest standard deviation scores for all operation questions.
- All devices get high mean values more than 3 in relation to how to operate and complexity to use.
- Mouse is consistently rated with high mean values and low standard deviation scores in relation to easy to use, operation and complexity to use.
- Mouse, touchpad and trackball get the mean values more than 3 in term of not to make mistakes.
- Hula pointer gets the lowest mean values for operational speed (2,38).
- Mouse, touchpad and trackball require low effort to be operated with the mean values more than 3.
- All devices have adequate interaction between their hardware and software with the mean values more than 3.

Device Design

The mean scores with items in relation to design of the devices can be seen in Table 3.9.

Table 3.9 The Mean Scores with Items in relation to Design of the Devices

Devices	mouse		touchpad		hula pointer		trackball	
Design Items	mean	sd	mean	sd	mean	sd	mean	sd
Q26-Design makes me feel positive towards use	4,23	0,53	3,14	1,23	2,61	1,20	3,42	1,24
Q27-Device design enhances its operation	4,23	0,53	2,85	1,27	2,42	1,02	3,33	1,27
Q28-Grip surface prevents slipping	4,38	0,49	3,00	1,30	3,00	1,22	3,23	1,44
Q29-Grasped easily	4,38	0,58	2,80	1,36	2,80	1,32	3,38	1,43
Q30-Can be positioned easily	4,28	0,64	2,71	1,27	2,57	1,24	3,42	1,43
Q31-Can be positioned quickly	4,33	0,65	2,76	1,26	2,38	1,24	3,33	1,39
Q32-Held without excessive effort	4,28	0,71	3,09	1,22	2,76	1,30	3,38	1,35
Q33-Design prevents inadvertent button activation	3,90	0,70	2,80	1,16	2,71	1,38	3,52	1,36
Q34-Shape of button assists finger positioning	4,23	0,53	2,71	1,27	2,57	1,20	3,42	1,36
Q35-Shape of button assists button actuation	4,14	0,65	2,80	1,20	2,66	1,19	3,42	1,39
Q36-Does not cause unintended pointer movement	3,85	0,96	2,57	1,20	2,33	1,15	3,28	1,34
Q37-Device accommodates hand size	4,38	0,49	2,66	1,35	2,52	1,24	3,42	1,28
Q38-Device is stable, does not slip/rock	3,42	1,24	3,14	1,31	2,80	1,24	3,47	1,36
Q39-Device weight does not impair usability	3,76	1,22	3,28	1,30	3,04	1,35	3,52	1,24
Q40-Satisfactory size	4,23	0,76	3,00	1,30	2,76	1,33	3,52	1,36
Q41-Satisfactory shape	4,28	0,56	3,04	1,24	2,80	1,43	3,33	1,39
Q42-Could reach all buttons	4,28	0,64	3,14	1,23	2,80	1,36	3,42	1,50

The results show that,

- Mainly, mouse gets the highest mean values and the lowest standard deviation scores for all design questions.
- Only the design of mouse creates positive feelings on the operators and enhances its operation with the mean value between 4 and 5. Then, trackball follows it with the mean values 3,42 and 3,33.

- Touchpad and hula pointer get the same and lowest scores in terms of grasping (2,8). In contrast all devices have mean values more than 3 regarding the grip surface.
- Hula pointer is consistently rated the lowest value with regard to positioning (2,57 & 2,38). Then, touchpad follows it with the mean values 2,71 and 2,76.
- Hula pointer gets the same and lowest scores with regard to holding without excessive effort (2,76). On the other hand, all devices have mean values more than 3 regarding the device weight.
- The designs of touchpad and hula pointer get low mean values for causing unintended pointer movement and button activation.
- Buttons size and shape of touchpad and hula pointer get lower mean values than mouse and trackball have.
- Trackball gets the highest mean value (3,47) in terms of being stable and not to slip.
- Touchpad and hula pointer get lower mean values in terms of accommodating hand size. On the other hand, only hula pointer gets low mean values for its size and shape (2,76 & 2,8).
- Reaching the buttons is more difficult for hula pointer with the mean value 2,8. In contrast, the participants rated mouse with 4,28.

Device Comfort

The mean scores with items regarding the comfort of devices can be seen in Table 3.10.

Table 3.10 The Mean Scores with Items regarding The Comfort of Devices

Device Comfort	mouse		touchpad		hula pointer		trackball	
	mean	sd	mean	sd	mean	sd	mean	sd
Q43-Does not cause pressure points	4,04	0,74	3,09	1,30	2,85	1,27	3,42	1,28
Q44-Used without deviations of hand	3,95	1,02	3,00	1,30	2,85	1,27	3,42	1,28
Q45-Used without deviations of fingers	4,04	0,74	2,95	1,28	2,66	1,19	3,47	1,28
Q46-Used without deviations of arm	4,04	0,58	3,09	1,26	2,76	1,26	3,61	1,32
Q47-Used without deviations of shoulder	4,00	0,63	3,09	1,26	2,71	1,23	3,66	1,35
Q48-Used without deviations of head	4,09	0,62	3,04	1,32	2,80	1,32	3,61	1,32
Q49-Used without deviations of neck	4,14	0,65	3,04	1,32	2,85	1,19	3,71	1,34
Q50-No finger fatigue	3,76	1,30	2,71	1,23	2,52	1,20	3,38	1,32
Q51-No wrist fatigue	3,28	1,34	2,61	1,20	2,47	1,20	3,42	1,32
Q52-No arm fatigue	3,76	0,99	2,76	1,22	2,52	1,24	3,52	1,32
Q53-No shoulder fatigue	3,95	0,86	2,90	1,30	2,57	1,24	3,52	1,32
Q54-No neck fatigue	4,14	0,65	3,00	1,34	2,66	1,23	3,47	1,32

The results show that,

- Mainly, mouse gets the highest mean values and lowest standard deviation scores for all comfort questions.
- Hula pointer gets the lowest mean values in terms of causing pressure points (2,85).
- With respect to high mean values, it can be stated that mouse can be used without deviations of hand, fingers, arm, shoulder, head and neck, which refers to unusual usage. Then, trackball follows mouse. However, hula pointer gets the lowest mean values for causing deviations.
- Mouse gets the highest mean value for not causing finger, arm and shoulder fatigues (3,76). On the other hand, trackball gets the highest mean value for not causing wrist fatigue (3,42).
- With respect of low mean values, it can be said that touchpad and hula pointer can cause finger, wrist, arm and shoulder fatigues.
- Mouse, touchpad and trackball get the mean values more than 3 for not causing neck fatigue.

As mentioned before, the statistical significance between the devices and between platforms of the participants were analyzed (Table 3.11& Table 3.12).

Table 3.11 Significance Values of the Platforms and the Devices

Tests of Between-Subjects Effects for Questions from 1 to 54

Significance for	All Questions	Device Performance	Device Operation	Device Design	Device Comfort
platform	**0,079**	0,168	0,001	0,310	0,334
device	**0,050**	0,002	0,000	0,002	0,048

Table 3.12 Significances of the Questions

for Platform

Effect	Sig.
Q17	0,036
Q18	0,035
Q20	0,005
Q25	0,031

for Device

Effect	Sig.
Q24	0,943
Q25	0,128
Q38	0,322
Q39	0,315

According to the results of the analysis, it is seen that the difference between the devices for the questions from 1 to 54 is statistically significant basing on $p \leq 0.05$. However, the difference between platforms for the questions from 1 to 54 is not statistically significant because the significance value is more than 0.05. In Table 3.11, the questions that have significant relationship for the platforms and the questions that do not have significant relationship for the devices are presented (Appendix G).

After the second part, the final part including four questions was analyzed. In this part, the operators were asked to rate the devices in terms of general operation, general comfort, general satisfaction and the participants' device preferences for the platforms where the devices are used for (the questions 55, 56, 57 & 58). To compare the results, mean values were calculated and if there is a significant difference between the devices and between the platforms was analyzed.

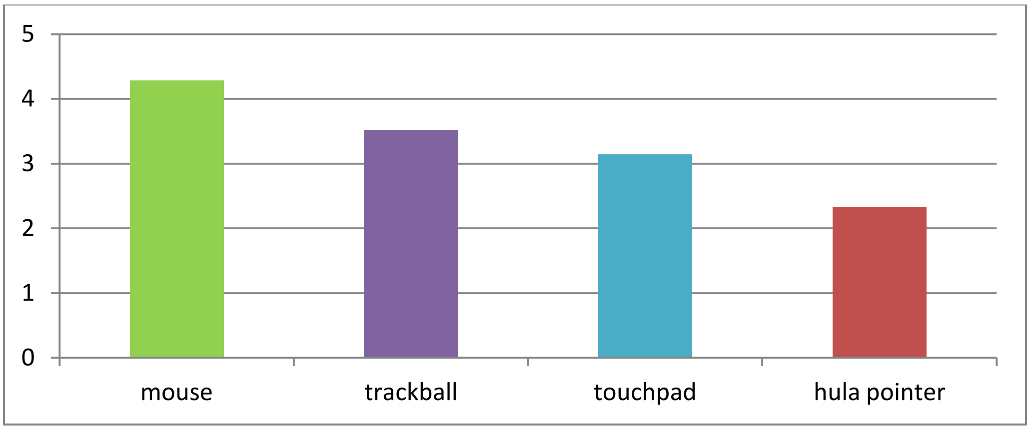

Figure 3.9 Mean Values for General Operation (all grades)

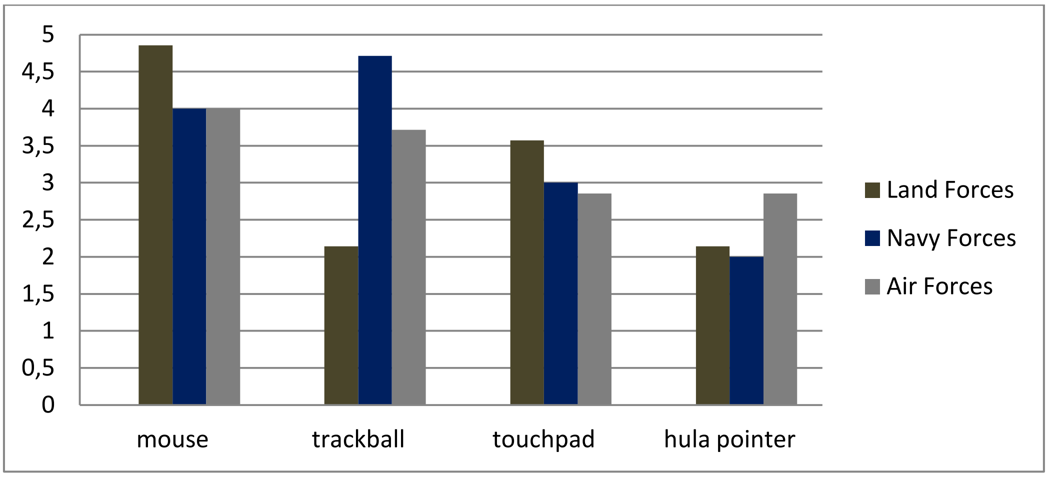

Figure 3.10 Mean Values for General Operation According to Platforms

As a result, mouse is thought the most satisfactory device for general operation. However, when the data concerning each platform are analyzed, mouse gets lower mean value than trackball from Navy Forces. As a second, trackball is chosen but trackball gets lower mean value than touchpad from Land Forces. They choose touchpad instead of trackball. Finally, hula pointer gets the lowest mean values from all platforms.

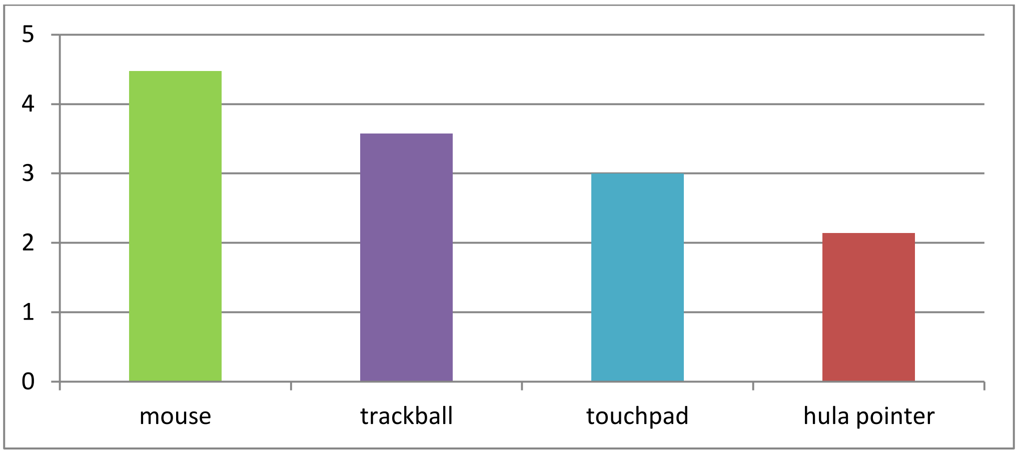

Figure 3.11 Mean Values for General Comfort (all grades)

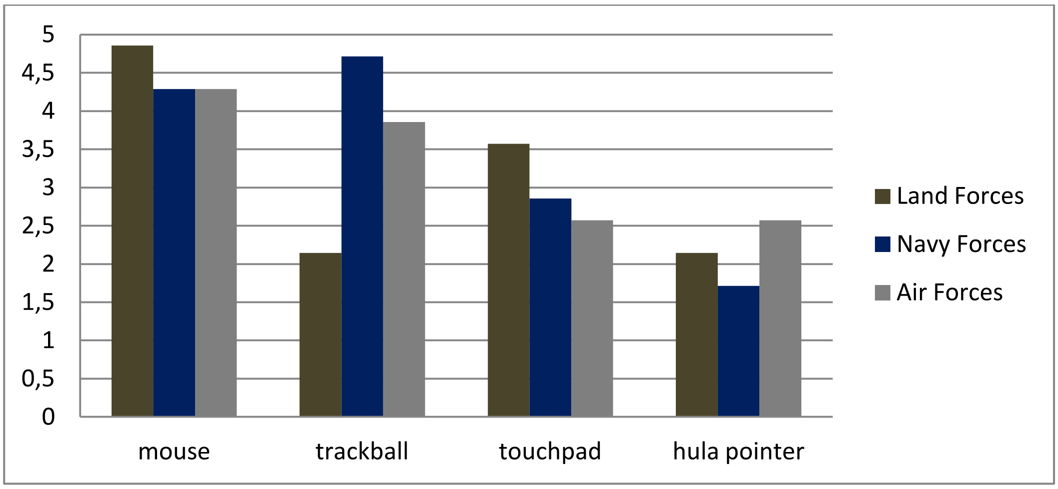

Figure 3.12 Mean Values for General Comfort According to Platforms

For the question regarding general comfort in the questionnaire, mouse is thought the most satisfactory device. On the other hand, when the data are analyzed in terms of the platforms, mouse gets lower mean value than trackball from Navy Forces. As a second, trackball is chosen basing on the total mean score but touchpad gets higher mean value than trackball from Land Forces. They choose touchpad instead of trackball. Finally, hula pointer gets the lowest mean values from all platforms.

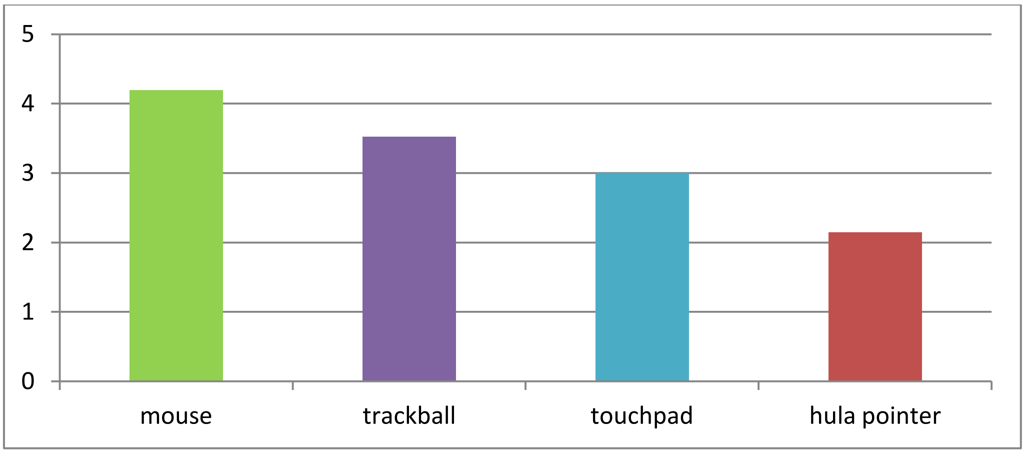

Figure 3.13 Mean Values for General Satisfaction (all grades)

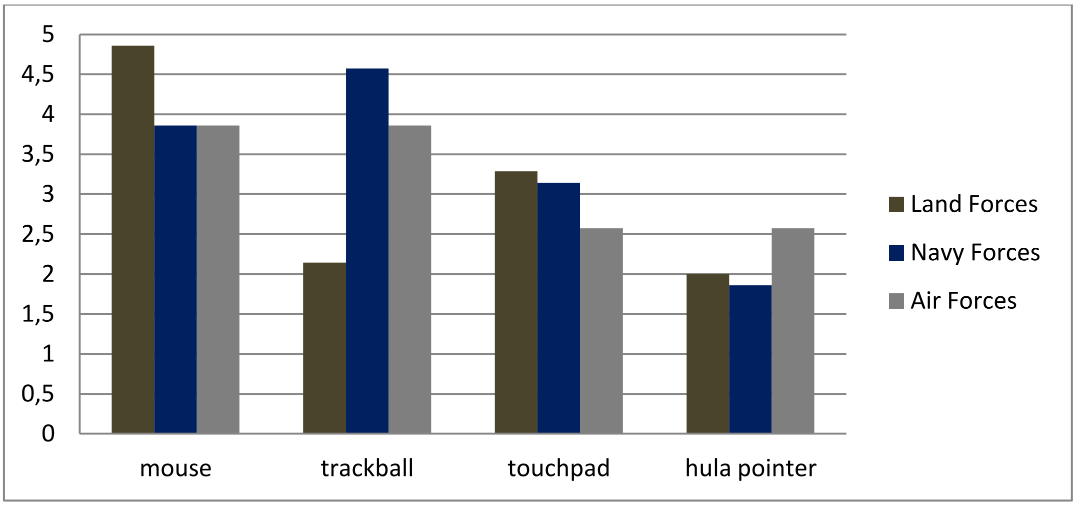

Figure 3.14 Mean Values for General Satisfaction according to Platforms

When the data collected from the question of general satisfaction were analyzed, it was realized that similar results were obtained with previous results. Mouse is thought the most satisfactory device for general satisfaction. But, trackball gets higher mean value than from Navy Forces and also, mouse gets the same mean value from Navy and Air Forces. Trackball is chosen as the second one but trackball gets lower mean value from Land Forces choosing touchpad instead of trackball. Finally, hula pointer gets the lowest mean values from all platforms.

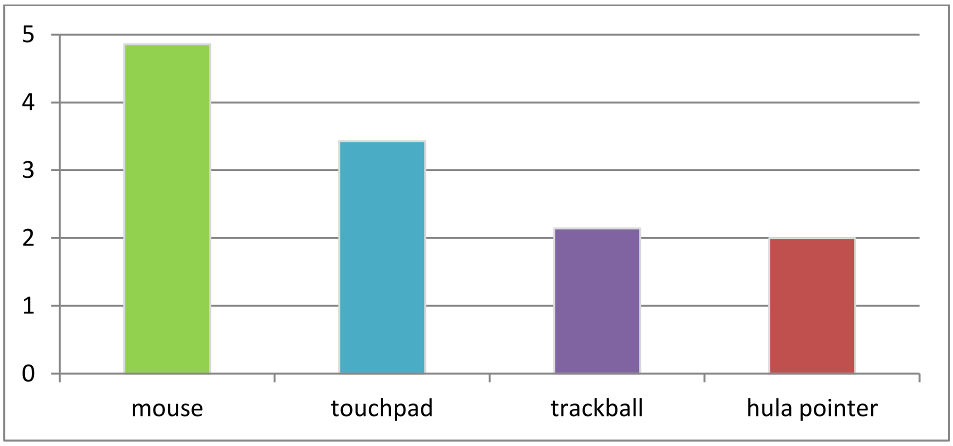

Figure 3.15 Mean Values for Device Preferences by Land Forces

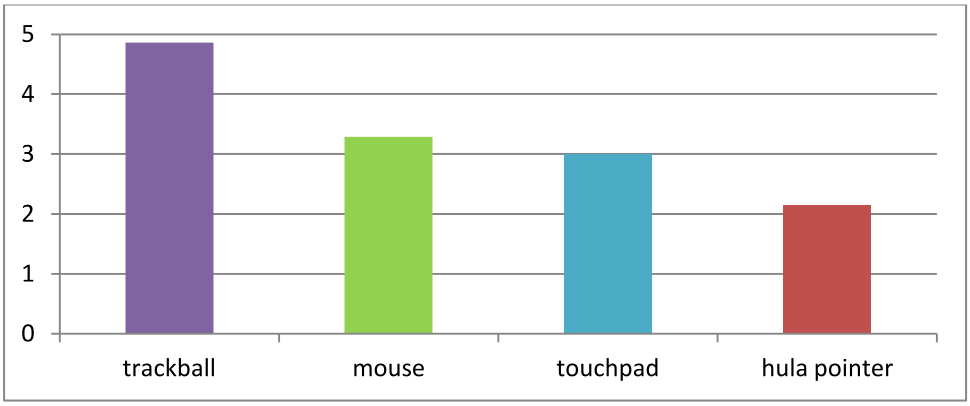

Figure 3.16 Mean Values for Device Preferences by Navy Forces

Figure 3.17 Mean Values for Device Preferences by Air Forces

As the final question of the questionnaire part, the operators rated the devices in relation to their preferences for their platforms. Although mouse was selected as the most satisfactory device by nearly all operators in the rest of the questionnaire, different devices were preferred by different platforms in this question. The results are:

- Land forces prefer mouse and then, touchpad gets high mean value from them (Figure 3.15)
- Navy forces prefer trackball and then, mouse gets high mean value from them (Figure 3.16).
- Air forces prefer touchpad as the most appropriate devices for their platforms. Then they prefer mouse as a second one (Figure 3.17).

While mouse and touchpad get higher mean values from Land and Air Forces, Navy Forces prefer trackball and mouse. The reasons of these results will be discussed in the next sections.

Table 3.13 Significances of the Questions from 55 to 58

Tests of Between-Subjects Effects for Questions from 55 to 58

Source	Dependent Variable	Sig.
Platform	Q55-general operation	0,760
	Q56-general comfort	0,699
	Q57-general satisfaction	0,671
	Q58-device preferences	0,002
Device	Q55-general operation	0,000
	Q56-general comfort	0,000
	Q57-general satisfaction	0,000
	Q58-device preferences	0,001

As mentioned before, significance values were analyzed in order to find out if the platforms and the devices have statistically effect on the results. According to results, there is a significant relationship only between the platforms and the question 58 regarding the device preferences. However, the relationships are statistically significant between the devices and the questions 55, 56, 57 and 58 (Table 3.13).

3.3.4.2 Results of the Focus Group Discussion Session

As the second part of the research study, the statements of the participants gathered in focus group sessions were analyzed thematically. To determine the sub-factors that affect satisfaction of the participants and understand their effects on them, the statements grouped basing on four factors stated in the quantitative study (Appendix H).

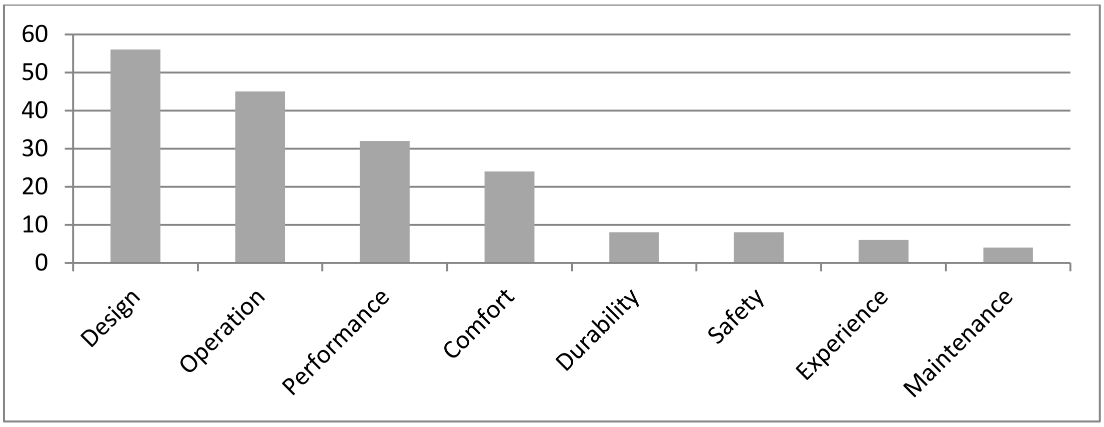

Figure 3.18 Number of the Statements Regarding the Factors That Affect Participants' Satisfaction

184 statements in total were coded and grouped in eight main categories and sixteen sub-categories (Figure 3.21).

Device Design

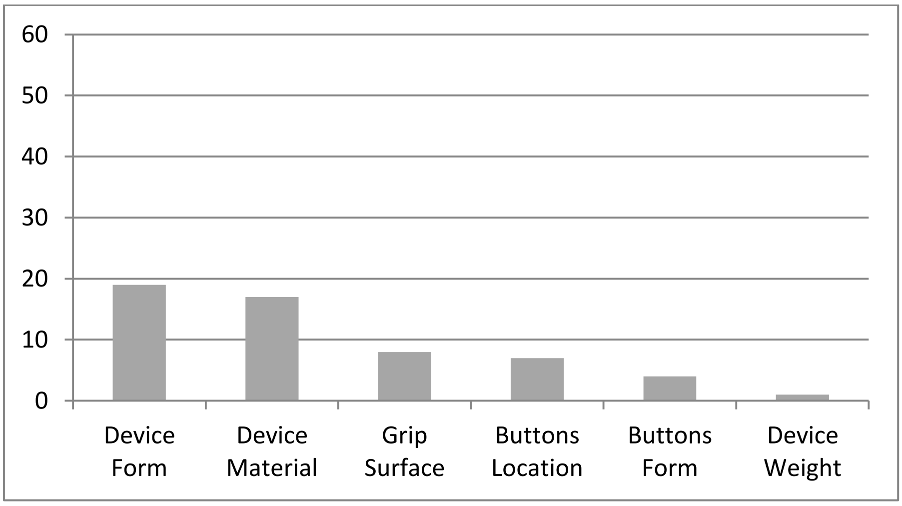

Figure 3.19 Number of the Statements Regarding the Sub-Factors under Device Design

Device Form

As seen in Figure 3.19, most statements are related to device form. Device form refers to visual shape of the devices. Statements related to forms of the devices are mainly about the shapes of the devices and sizes of the devices. For instance, one of the participants states that “size of touchpad should be bigger.” Another statement is that “because of the shape of hula pointer, it is hard to hold.” Another participant states that these “devices are not suitable for left hand usages.” It can be concluded from the statements that device form also affects comfort and performance of the devices.

When the data were analyzed according to the platforms, it was realized that statements were mentioned by Air Forces at most. They talked about the forms of all devices. However, although device form is the mostly mentioned sub-factor for Navy Forces, they did not make any criticism in relation to the form of touchpad.

Device Material

Most used materials for the devices are plastic and metal. Mostly used plastic type is industrial silicone rubber and mostly used metal type is stainless steel.

Statements related to device material are mainly about impermeability, hygiene, aging of material, strength of material and sensitivity of material. For instance, one of the participants states that “plastic buttons are very soft and this affects sensitivity.” Another statement is that “because of metallic surface, when the environment is cold, the surface becomes cold.” Other one is that “buttons break off easily.” Also, another participant mentions that “when the material of trackball gets dirty because of long working hours in which the operators sometimes do not leave their positions, the device works slower.” It can be concluded from the statements that device material also affects performance of the devices.

The data were analyzed according to the platforms and it was found that statements were mentioned by Air Forces at most and also, device material is the most important sub-factor for Air Forces. They mainly talked about the material of hula pointer and trackball.

Grip Surface

Statements related to grip surface mainly are about form and material of the grip parts. For instance, one of the participants states that “grip surface of mouse prevents slipping.” Another statement is that “it is hard to hold trackball because of its ball.” Other one is that “hula pointer does not accommodate hand.”

According to the platforms specific results, statements were mentioned by Land Forces at most and also, grip surface is the most important sub-factor for Land Forces. They mainly talked about the grip parts of hula pointer and mouse.

Buttons’ Location

Statements related to buttons location mainly are about the place of the buttons and their accessibility. For instance, one of the participants states that “the place of hula pointer’s buttons is suitable to reach.” Another statement is that “it is hard to use trackball because the buttons are far away from the ball.” Another one is that “the buttons can be close to each other.”

When the data were analyzed according to the platforms, it was realized that statements were mentioned by Air Forces at most. They mainly talked about the buttons' locations of hula pointer and trackball.

Buttons' Form

Statements related with the buttons' form are mainly about the shape and size of buttons. For instance, one of the participants states that "their hands are big and they use gloves." But because the "buttons are small, they push the buttons at the same time accidentally."

Also, it was found that statements were mentioned by Land Forces at most. They mainly talked about the form of the buttons of hula pointer and trackball.

Device Weight

Statements related to device weight are mainly mentioned by only Land Forces. They say that "mouse is a very light device" as a positive design feature.

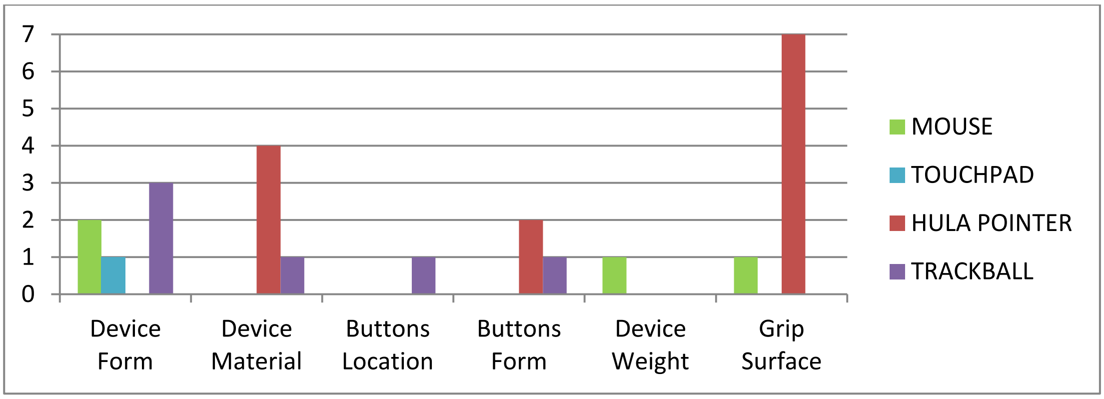

Figure 3.20 Frequency of the Sub-Factors under Device Design by Land Forces

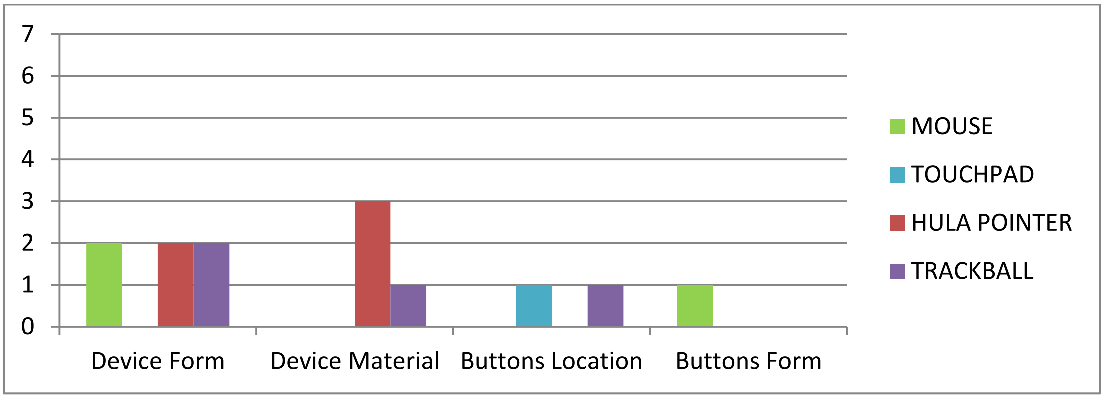

Figure 3.21 Frequency of the Sub-Factors under Device Design by Navy Forces

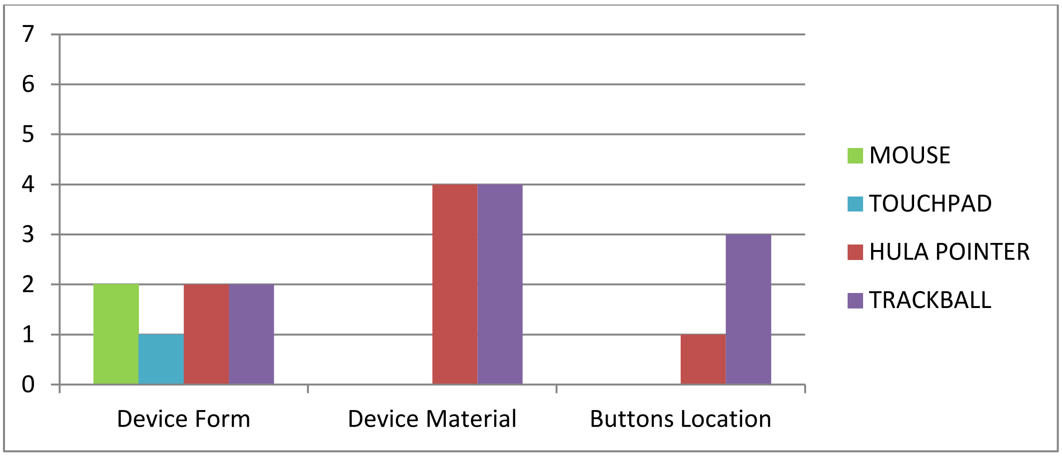

Figure 3.22 Frequency of the Sub-Factors under Device Design by Air Forces

Device Operation

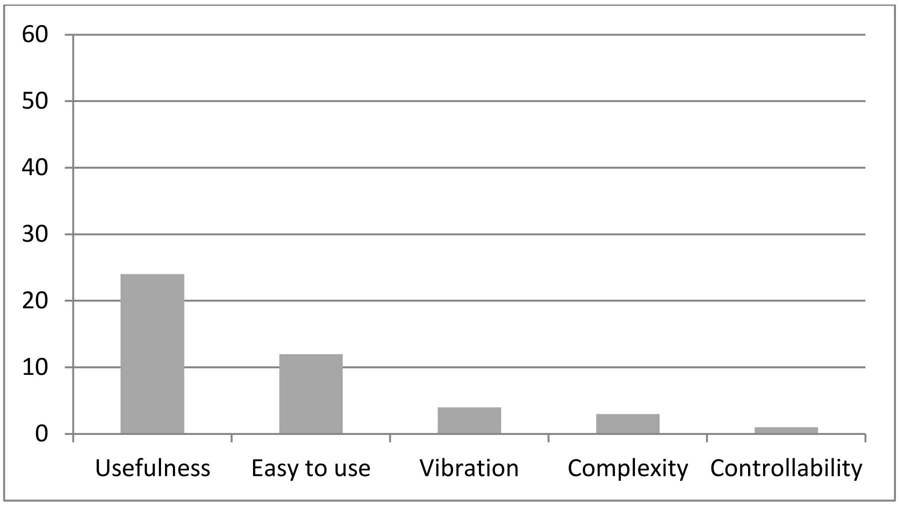

Figure 3.23 Number of the Statements Regarding the Sub-Factors under Device Operation

Usefulness

As seen in Figure 3.23, most of the statements are related to usefulness. They are mainly about the usage of devices. For instance, one of the participants states that "touchpad requires both hands usage and so, it is not useful." Other states that "it is hard to turn the ball and push the buttons at the same time while using trackball."

When the data were analyzed according to the platforms, it was realized that statements were mentioned by Navy Forces at most and also, it is the most important sub-factor for Navy Forces.

Ease of Use

One of the statements related to ease of use is mentioning that “mouse is easy to use.” Other statement is saying that “everybody can use mouse easily.” Another participant is stating that “it is easy to learn how to operate mouse.”
According to the results, it was seen that statements were mentioned by Land Forces at most. They mainly talked about the ease of use of the touchpad, hula pointer and trackball.

Vibration

One of the statements related to vibration is “using mouse is hard to use in vibration.” Another statement by Navy Forces is that “vibration affects the operation of mouse and performance of the participants.”

According to the platform specific results, statements were mentioned by Navy Forces at most. They mainly talked about the usage of mouse in vibration.

Complexity

One of the statements related to complexity is, for instance, “mouse is a practical device.”

When the data were analyzed according to the platforms, it was realized that statements were mentioned by Navy Forces at most and they mainly talked about the complexity of mouse.

Controllability

One of the statements related to controllability is that “the control of hula pointer is difficult.”

The data were analyzed according to the platforms and it was found that statements were mentioned by Air Forces at most and they mainly talked about the controllability of hula pointer.

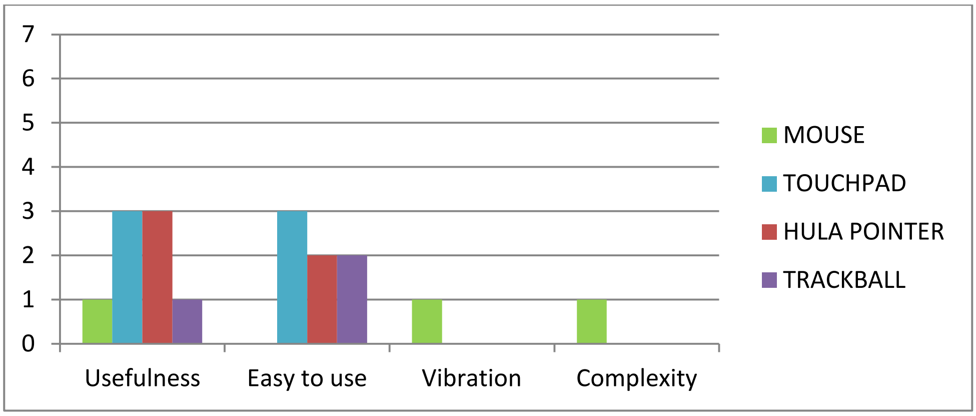

Figure 3.24 Frequency of the Sub-Factors under Device Operation by Land Forces

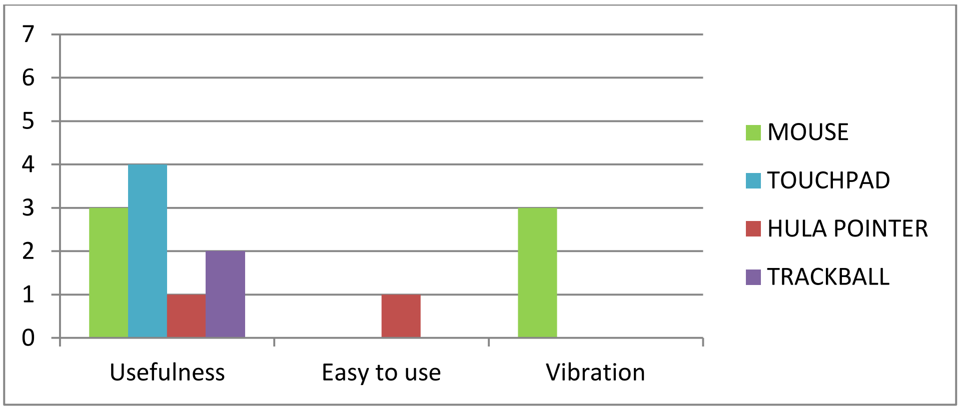

Figure 3.25 Frequency of the Sub-Factors under Device Operation by Navy Forces

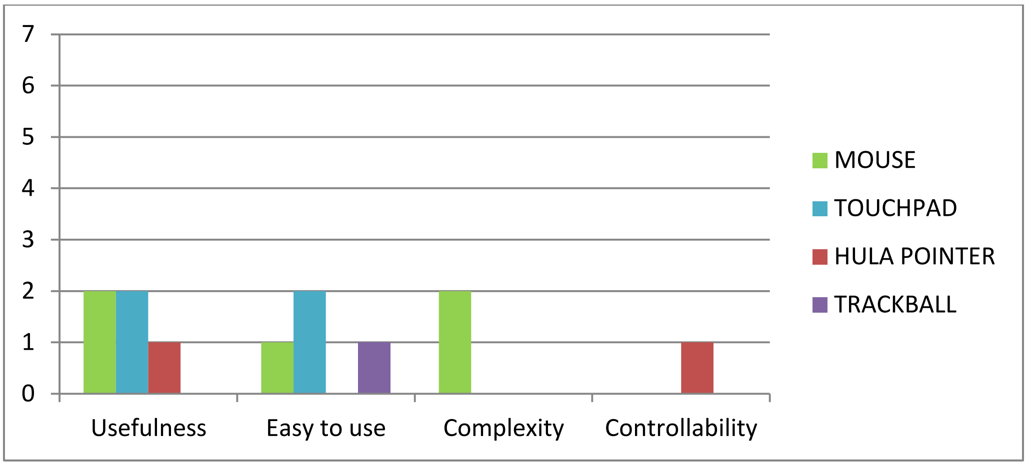

Figure 3.26 Frequency of the Sub-Factors under Device Operation by Air Forces

Device Performance

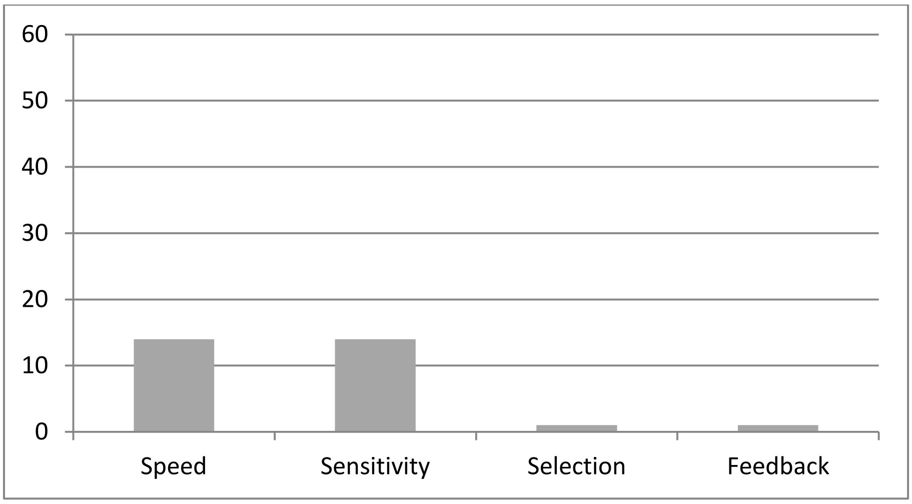

Figure 3.27 Number of the Statements in relation to Sub-Factors under Device Performance

Speed and Sensitivity

As seen in Figure 3.27, most of the statements are related to speed and sensitivity. One of the statements related to these points is that “mouse is very fast and sensible device but trackball and hula pointer are very slow and are not sensible enough.” Also, they mention that “material affects sensitivity.”

When the data were analyzed according to the platforms, it was realized that statements for speed and sensitivity were mentioned by Land Forces at most. Also, sensitivity is the most important sub-factor for Land Forces. They mainly talked about the hula pointer and trackball.

Selection and Feedback

One participant from Navy Forces claims that “it is hard to make selection with hula pointer” and another one from Land Forces mentions that “touchpad gives feedback slowly.” It can be said that these factors are affective for the performance of devices.

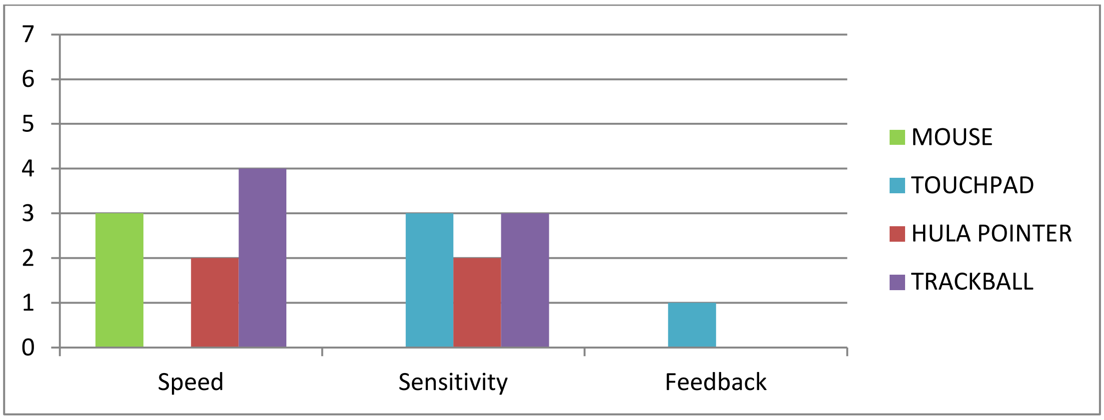

Figure 3.28 Frequency of the Sub-Factors under Device Performance by Land Forces

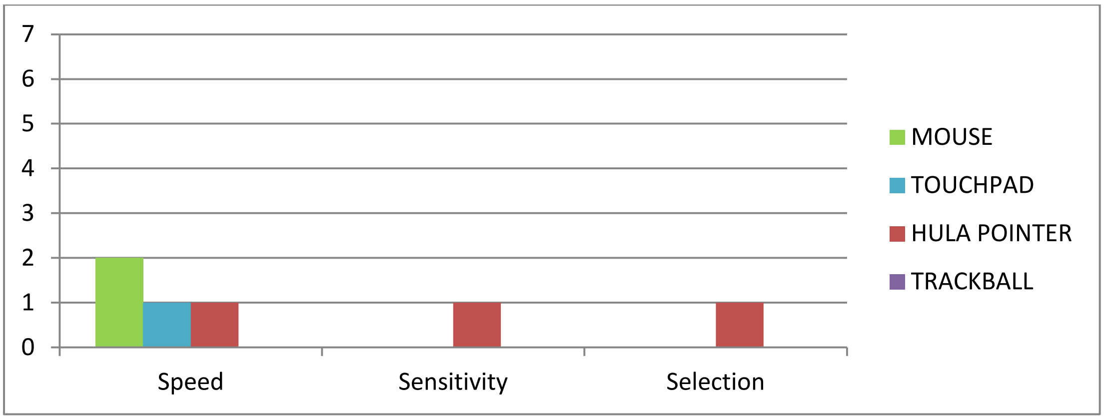

Figure 3.29 Frequency of the Sub-Factors under Device Performance by Navy Forces

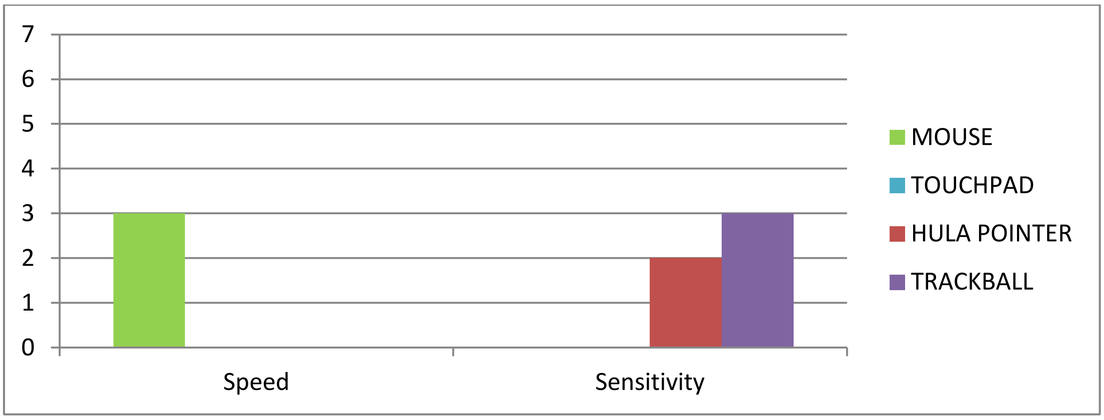

Figure 3.30 Frequency of the Sub-Factors under Device Performance by Air Forces

Device Comfort

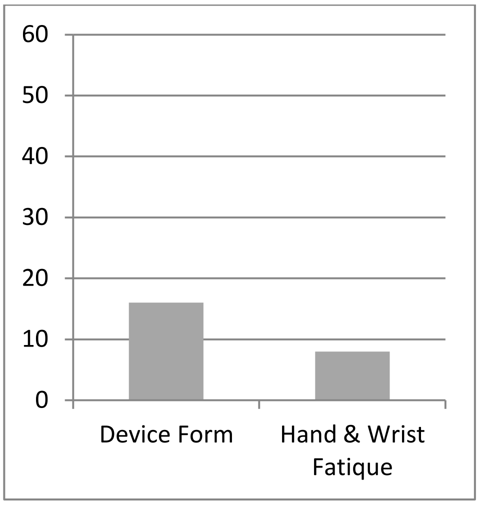

Figure 3.31 Number of the Statements in relation to Sub-Factors under Device Comfort

Device Form

As seen in Figure 3.31, most statements are related to device form. They are mainly about holding the device and device accommodation for hand. For instance, one of the participants states that “mouse is grasped comfortably.” Another statement is that “trackball causes hand and wrist pain.” The participants also mention that “mouse accommodates hand size.”

As other factors, when the data were analyzed according to the platforms, it was seen that statements were mentioned by Navy Forces at most. They talked about mouse, trackball and hula pointer. Also, sub-factor of device form is mentioned mostly by all Forces.

Hand and Wrist Fatigue

The participants mainly state that "the devices, especially trackball and hula pointer, cause hand and finger pain and wrist fatigue."

Also, according to the results, it was realized that statements were mentioned by Air Forces at most. They talked about the mouse and trackball.

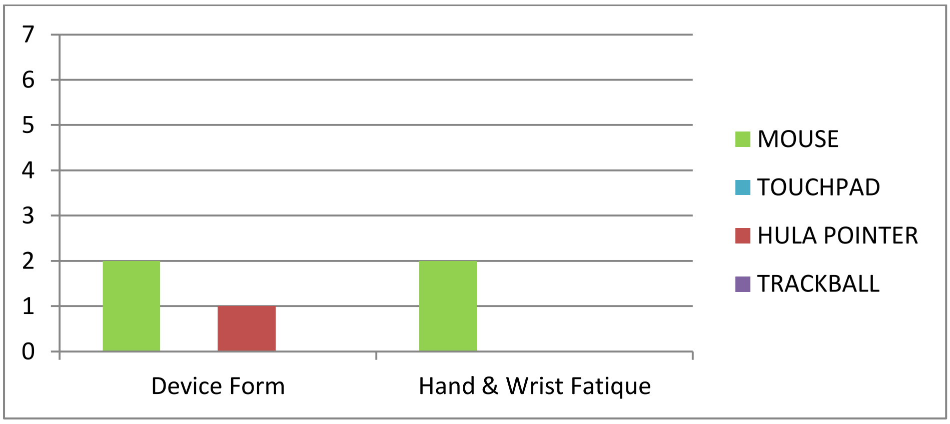

Figure 3.32 Frequency of the Sub-Factors under Device Comfort by Land Forces

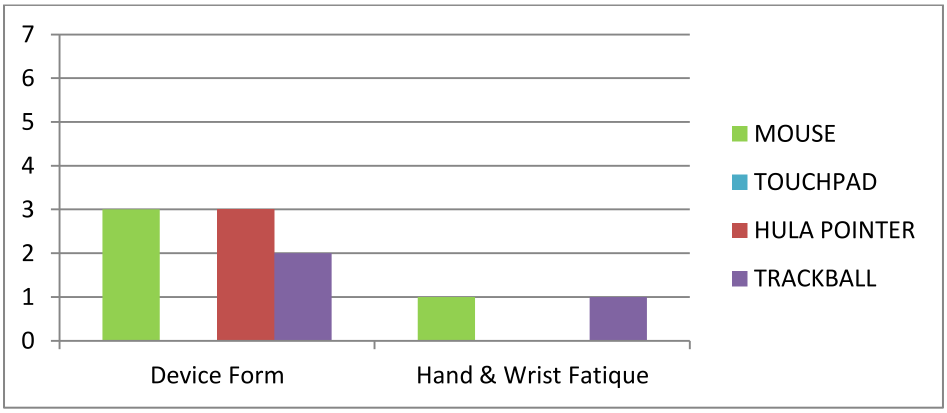

Figure 3.33 Frequency of the Sub-Factors under Device Comfort by Navy Forces

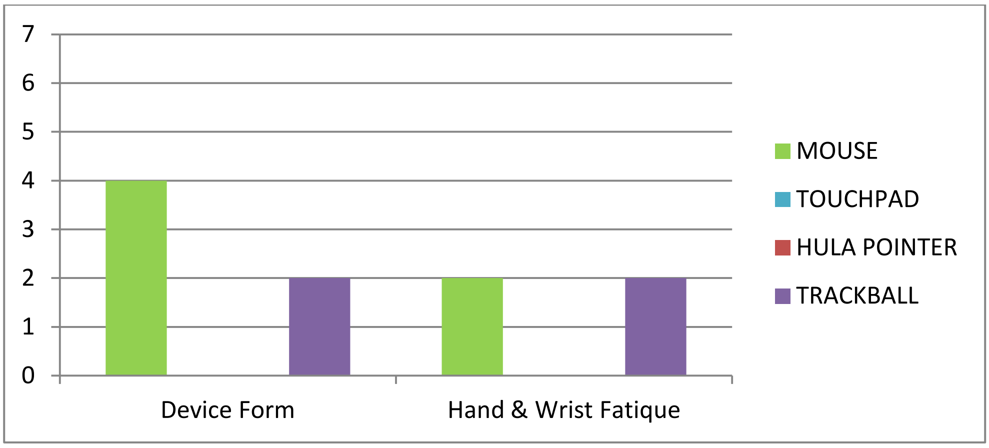

Figure 3.34 Frequency of the Sub-Factors under Device Comfort by Air Forces

Durability, Safety, Experience and Maintenance

Durability is related to lifetime of the devices. The participants claim that “it is important for all devices not to break off easily.” They also mention that “the devices should be reliable in both normal and emergency conditions.”

Safety refers to the qualities of the devices that can cause dangerous situations in emergency conditions. It is meaningful to state that according to the participants, “the devices should be fixable because of safety requirement and so, mouse is not a suitable device for emergency conditions.”

According to the participants, experience is an affective factor for their satisfaction. They indicate that “they have used mouse, trackball and touchpad for a long time.” Especially, they use mouse and touchpad in their daily lives. This is also related to their habits. However, they begin to use hula pointer for a shorter time because it is a newer device than others.

Maintenance provides the continuity of the mission. Systems are required to work in any emergency situations. Hence, the participants claim that “the devices should be easy to handle and replaceable for the maintenance of the task.”

In the next chapter, the findings of the study will be discussed and the thesis will be concluded by revisiting the research questions.

CHAPTER 4

DISCUSSION AND CONCLUSION

This chapter presents discussion of the research study findings and a brief review of the answers to the research questions of this thesis regarding the literature survey in Chapter 2 and field studies presented in Chapter 3. The chapter ends with determining the limitations of the study and providing suggestions for further research.

4.1 Recommendations and Discussion

The aim of this study was to assess NKIDs used in military in order to determine the factors affecting the usage of them in relation to user satisfaction and generate design recommendations. Accordingly, a questionnaire and focus group discussion were conducted among 21 military operators from three different garrisons.

In the questionnaire, four NKIDs were evaluated by the participants in terms of design, comfort, operation and performance with 58 measuring items. According to results, mostly mouse got the highest mean values and hula pointer got the lowest mean values. In addition, it can be said that mouse is the most satisfactory device among the product samples according to the participants. Also, based on ANOVA analysis it can be said that platform differences did not affect the results. Only, the result of last question related to device suitability for the platforms was affected by platform differences. In addition, platform specific information was gathered from focus group discussion session.

Following the questionnaire session, the participants were asked to mention their suggestions and preferences regarding the design of devices. As a result, platform specific and general design recommendations are generated for the integration and selection of the devices.

Platform Specific Device Characteristics

According to the preferences of the participants from Land Forces, it would be better that the devices have the characteristics listed below.

- Ability of being fixable for safety requirements,
- Ability of being durable or replaceable easily,
- Having bigger buttons, balls and grip parts for gloves,
- Ability of being impermeable,
- Consisting of hygienic materials.

As for Navy Forces, the highlighted device characteristics are as follows:

- Ability of being endurable dust and water,
- Ability of being durable,
- Ability of being replaceable easily.

Furthermore, device characteristics preferred by Air Forces are listed below.

- Ability of being appropriate for hand size,
- Ability of being fixable for safety requirements,
- Ability of being endurable dust and water.

General Design Recommendations in relation to User Satisfaction for NKIDs

- Place, size and shape of the buttons are important for the operators. They need to reach all buttons and push the buttons separately. Otherwise, excessive effort may result in pain or injury. Also, military operators wear gloves in emergency condition. This situation should be taken into consideration. Also, MIL-STD-1472G includes information about buttons' characteristics, such as resistance and displacement.

- Subjective statements concerning hula pointer indicates that handgrip does not accommodate hand size and shape. This may cause wrist and finger fatigue. Also, surface of grip should prevent slipping.

- Shape and weight of a device is important for operators' comfort. While designing the devices, both usage of right and left hands might be considered. Otherwise, awkward postures can lead to some wrist deviations. Similarly, MIL-STD-1472G gives detailed dimensions for the devices.

- Material of the devices might be chosen by considering military conditions. Because of the long mission hours and environmental conditions, devices frazzle quickly and thus, device can break into pieces. In addition, material should able to be long- lasting. Also, material can have protection against dust, water and corrosive liquids.

- Device can be designed to allow the usage of devices by one hand. Also, MIL-STD-1472G adds that the devices can be operated by either the left or right hand.

- Device can give feedbacks to the operators on how to use. For example, there can have symbols and labels on their buttons.

- Device is able to give rapid responses and it is important that operators can control the devices and select the targets easily.

- Devices can be designed replaceable. When the device does not work, a new one can be found easily. In this context, most operators mention that mouse is a good device because there are wide varieties of it.

- Devices can be updated according to new technological developments. In this context, more importance can be given to the maintenances of the devices.

- Accessories of the devices such as mouse mat can be chosen according to comfort of the operators. In the consoles, there is a limited space. So, the accessories might be in an adequate size.

When the findings of research study are compared with MIL-STD-1472G, it is realized that MIL-STD-1472G contains design criteria for only mouse and trackball. Similar to results of the thesis, MIL-STD-1472G gives importance to hand grasp, smooth movement, handedness, buttons, shape and dimensions of the devices. On the contrary, MIL-STD-1472G does not cover any information about safety, durability, accessories, impermeability and material of these devices.

As mentioned before, in the focus group session, the participants were asked to evaluate four NKIDs with their subjective statements and identify the factors that influence their satisfaction in relation to the usage of these devices. As mentioned before in Figure 3.19, 184 statements were gathered in the discussions and they were categorized under the factors mentioned in the previous sections. As a result, it can be indicated that the most significant factor affecting the satisfaction of military operators is device design.

In both questionnaire and focus group sessions, mouse was selected by the participants as the most satisfactory device. Trackball and touchpad followed the mouse and it can be stated that hula pointer is the least satisfactory device. The reason of this result can be related to experience of the participants beside the other factors. Participants have used mouse, trackball and touchpad for a long time. On the contrary, hula pointer has been used for a short time because it is newer than other devices. In addition, it can be meaningful that the operators can be encouraged to use hula pointer more in the future and so, they can get more experience with hula pointer. Another result of the study is that although mouse gets high mean values from the participants, when the participants are asked to rate the devices according to fitness to their platforms, only Land Forces prefer mouse. Navy Forces select trackball and Air Forces select touchpad. As a reason, it can be stated that operators of Navy Forces prefer trackball because of their long time experience with trackball and Air Forces prefer touchpad because of safety issues. In fact, in emergency situation, high vibration is felt in the aircraft. Therefore, all devices should be fixed to prevent any injury. In this context, it can be concluded that experience and safety are also effective factors in military.

Moreover, the participants mention that issues of durability and maintenance can be taken into consideration in terms of the integration and selection of NKIDs.

4.2 Research Questions Revisited

It was tried to answer the research questions proposed in the first chapter with the literature review and the research study. The answers of these questions were explained in different chapters of the thesis as illustrated in Figure 4.1.

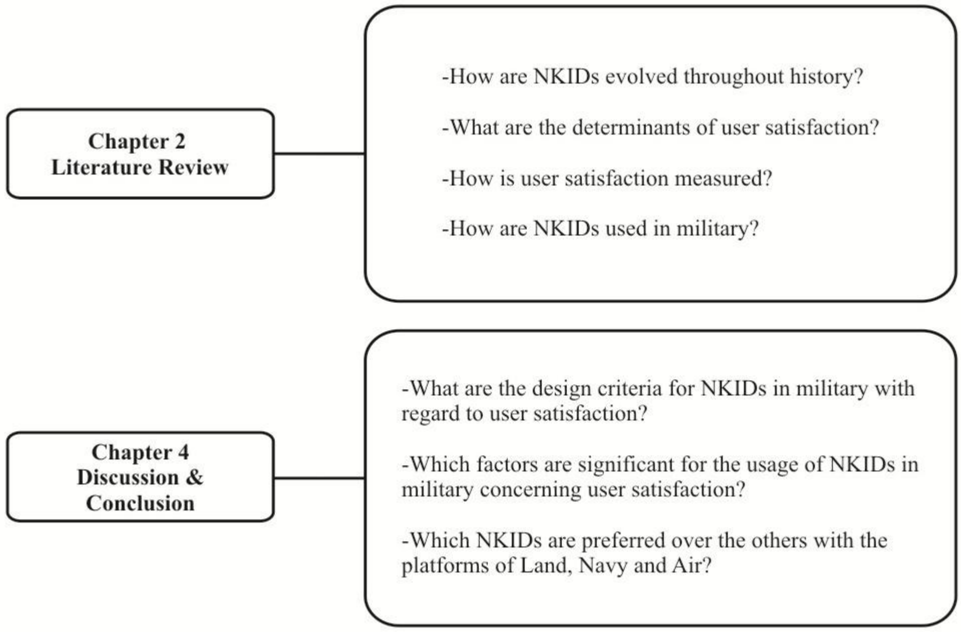

Figure 4.1 Research Questions and Related Chapters

Q1. How are NKIDs evolved throughout history?

To answer this question, the literature was scanned and the answer of this question was tried to be explained through the first section of the literature review. In Chapter 2, historical background of computer and input devices were summarized. Then, keyboards and non-keyboard input devices were explained as the types of input devices. As the answer of this question, when the types of NKIDs were examined, it was seen that although light pen was the first NKID, it did not show a great improvement during the years. However, mouse was invented after light pen and joystick and has been developed during the years. Also, other devices, such as touch screen and touchpad provided the users new functions and features. However, researchers have continued to study on mouse.

Q2. What are the determinants of user satisfaction?

The answer of this question was tried to be explained in the second section of the literature review study. In the second chapter, the determinants of user satisfaction were examined in detail. One of these determinants is *functionality* described as the performance of a product (McNamara & Kirakowski, 2005). In the literature, it is mentioned that dissatisfaction results from poor functionality (Chiang et al, 2000). In fact, HCI discipline has measured user satisfaction by performance related tools for a long time. But, functionality is not the only factor. Lindgaard and Whitfield (2004) state that *Aesthetics* is one of the significant determinants for user satisfaction. While in the beginning, HCI discipline was focusing on only performance, today, it began to examine the correlations between aesthetics and user satisfaction. The recent interest in aesthetics exposes that there are other factors that influence satisfaction. Beside aesthetics, there is a growing interest in *user experience*, especially for HCI discipline. HCI discipline states that experience with a product generates *emotional consequences* on users such as satisfaction and pleasure. As a final determinant, it was seen in the literature that *product design* elements have a significant effect on user satisfaction.

Q3. How is user satisfaction measured?

The answer of this question was investigated with the literature in Chapter 2. User satisfaction as a subjective side of usability is measured by wide varieties of methods like inspection method. However, inquiry method is mainly used because it is benefitted from questionnaires and interviews which are based on users' subjective comments as an evaluation tool (Ryu, 2005). In the light of scanned literature, it was realized that there were large volumes of usability questionnaires developed in HCI discipline such as Questionnaire for User Interaction Satisfaction (QUIS) (Chin et al., 1988), Software Usability Measurement Inventory (SUMI) (Kirakowski and Corbett, 1993), Post-Study System Usability Questionnaire (PSSUQ) (Lewis, 1995), System Usability Scale (SUS) (Brooke, 1996), Purdue Usability Testing Questionnaire

(PUTQ) (Lin et al., 1997), End-User Computing Satisfaction Instrument (EUCSI) (Doll & Torkzadeh, 1988), Technology Acceptance Model (TAM) (Davis, 1991) and also, in industrial design discipline, it was found that there were recently developed questionnaires such as Mobile Phone Usability Questionnaire (MPUQ) (Ryu, 2005) and Consumer Product Questionnaire (CPQ) (McNamara, 2006). When all these questionnaires were analyzed in detail, it was found that the questionnaire of Wood et al (2002) was more suitable for this thesis subject.

Q4. How are NKIDs used in military?

The answer of this question was given in the last sub-section of the literature review in Chapter 2. Standards and handbooks are indispensable sources for both military and civil defense industries. They include general requirements and criteria for the design of systems and products; and also, give general information about the environmental conditions and test procedures. Input devices in military are integrated on the military console, which is a workstation of an operator who is a soldier in a special mission and an expert user of a console. As related to thesis subject, general design criteria and information for input devices were determined by standard of MIL-STD-1472G.

Q5. What are the design criteria for NKIDs in military with regard to user satisfaction?

The design recommendations based on the results of research study were explained in detail in section 4.1. Briefly, these recommendations are related to place, size and shape of the buttons and handgrips, shape, weight and material of the device, single hand usage, performance and accessories for the devices.

Q6. Which factors are significant for NKIDs in military concerning user satisfaction?

In the Chapter 3, the results of research study showed that significant factors affecting satisfaction of military operators is respectively device design, device operation, device performance and device comfort. Also, they mentioned that issues of durability, maintenance, experience and safety are affective factors in military and they should be taken into consideration in terms of usage and design of NKIDs.

Q7. Which NKIDs are superior to the others in terms of platforms which are Air Forces, Navy Forces and Land Forces?

The literature review could not answer this question and so, the research study was conducted. According to the results of the questionnaire, although mouse got high ratings from the participants, when the operators were asked to rate the devices according to usability in their platforms, mouse was preferred by only Land Forces. While Navy Forces selected trackball because of long time experience, Air Forces selected touchpad because of safety issues.

4.3 Concluding Remarks

The purpose of the industrial design discipline is to build a connection between user and product. Therefore, industrial designers design products concerning a wide range of dimensions, such as aesthetics, functionality and usability, to answer user needs and satisfy them. But, it is a challenging task to create satisfactory products. In addition, researchers investigate the factors that influence user satisfaction and they try to generate some design recommendations for the designers.

However, in the light of the scanned literature, it was realized that military products are not taken into consideration in most of these studies. In addition, the aim of this study was to focus on the military products in relation to user satisfaction. It aims to evaluate NKIDs used in military in terms of user satisfaction. In this context, the research study including a preliminary and a main study was carried out. Questionnaire and focus group discussion techniques were used as the measurement tools. In the preliminary study, 51 operators selected two most satisfactory devices and two least satisfactory ones. Then, the research study was conducted. In the main study, 21 operators, including seven out from Land Forces, seven from Navy Forces and seven from Air Forces, performed three tasks and then, they filled out the questionnaire to assess the devices. Although the questionnaire was prepared for a health organization, it includes useful and common items for thesis study. But, it needed some modifications and so, it was revised. Now, it can be used for other research studies. After the questionnaire session, the participants expressed their subjective evaluations in focus group discussion.

As a result of the study, qualitative and quantitative data were compared and as mentioned in section 4.1, platform specific device characteristics and design recommendations were generated. Also, as it can be seen in Table 4.1, mouse was found as the most satisfactory device in terms of device design, operation, performance and comfort with the questions from 1 to 54 as the second part of questionnaire of the main study. However, suitability of the devices was compared according to which platform used in and the results indicated that mouse was preferred only by the participants from Land Forces. While Navy Forces were preferring trackball, Air Forces chose touchpad as the most appropriate devices.

Table 4.1 Review of the Results of Questionnaire Session of the Main Study

	Land Forces	Navy Forces	Air Forces
Questions1-54	mouse	mouse	mouse
General Operation	mouse	mouse	mouse
General Comfort	mouse	mouse	mouse
General Satisfaction	mouse	mouse	mouse
Device Preferences in terms of Platforms	mouse	trackball	touchpad

To conclude, the results of research study can provide new information to companies and designers. For example, in Aselsan, the same devices are offered to all platforms. But, in the light of this study, the devices can be integrated to the platforms based on platform specific device characteristics or the devices can be modified according to these characteristics. Also, interesting details were gathered from the participants. For instance, although the devices made of silicone are presented to users in Aselsan, the participants mention that this material is not durable and useful. So, to solve this problem, different material types can be explored or existing materials can be modified. As a result, by the help of research study, meaningful design criteria can be obtained.

4.4 Limitation of the Study

This study has some limitations because of military conditions.

Firstly, the preliminary study was carried out by the pictures of the devices. But, in the main study, the participants were provided with four real devices to use.

Secondly, the main study was conducted in three different military garrisons. The audio-visual data recording was not allowed because of military rules. During the discussions, the author took notes because of military rules. So, the data analyzed for the focus group discussion are limited by the author's notes.

Another limitation was that a limited number of participants attended to the study because it is difficult to find a large number of operators in the garrisons. Generally, there are few operators and also, because of security restrictions, the operators performed representative tasks instead of real tasks in the main study. Otherwise more detailed information can be gathered from more operators performing real tasks.

Lastly, because operators have regular training or missions; it was not possible to make meetings with operators one by one. There was limited time to make the main study. Therefore, focus group discussion and the questionnaire were preferred instead of in-depth interview. Otherwise more information can be obtained through in-depth interviews with operators. So, the results of the qualitative study are limited by focus group discussion made in limited time.

4.5 Further Research

The aim of this thesis study is to define the factors that influence user satisfaction for military NKIDs and generate design recommendations. Through the study, existing user satisfaction measurement tools were analyzed in terms of their extent and applicability in military context since there was no specific study for military users. Therefore, a detailed questionnaire for NKIDs was used for the research study. As a further study, a satisfaction model or scale can be generated for NKIDs or the questionnaire used in the research study can be improved.

It is also seen that qualitative studies are more valuable to understand perspectives of military users. In the existing research study, focus group discussion method was used because of time limitations. It could be valuable to make in-depth interviews with the samples.

Similar research studies can be conducted with the operators who do not use these devices before. It can be meaningful to compare experienced and inexperienced device users to get more valuable information.

This research did not focus on a particular factor of satisfaction in detail. Further studies can focus on some specific factors such as device comfort and examine that factor more deeply.

In the present study, four types of products - mouse, hula pointer, touchpad and trackball - were studied. But, there are wide varieties of types for those devices, especially for mouse. To generalize the design criteria, further studies can be focus on different product types. With larger questionnaire samples and varying product groups, the research domain can be extended in order to make some generalizations.

To conclude, as it is seen from the findings of this thesis, although the related literature is equipped with numerous studies focusing on user satisfaction, there are not enough studies carried out by researchers on military context. Since user satisfaction is a challenging and multidimensional research area, each new research makes a significant contribution to that area, especially for the researchers from industrial design discipline.

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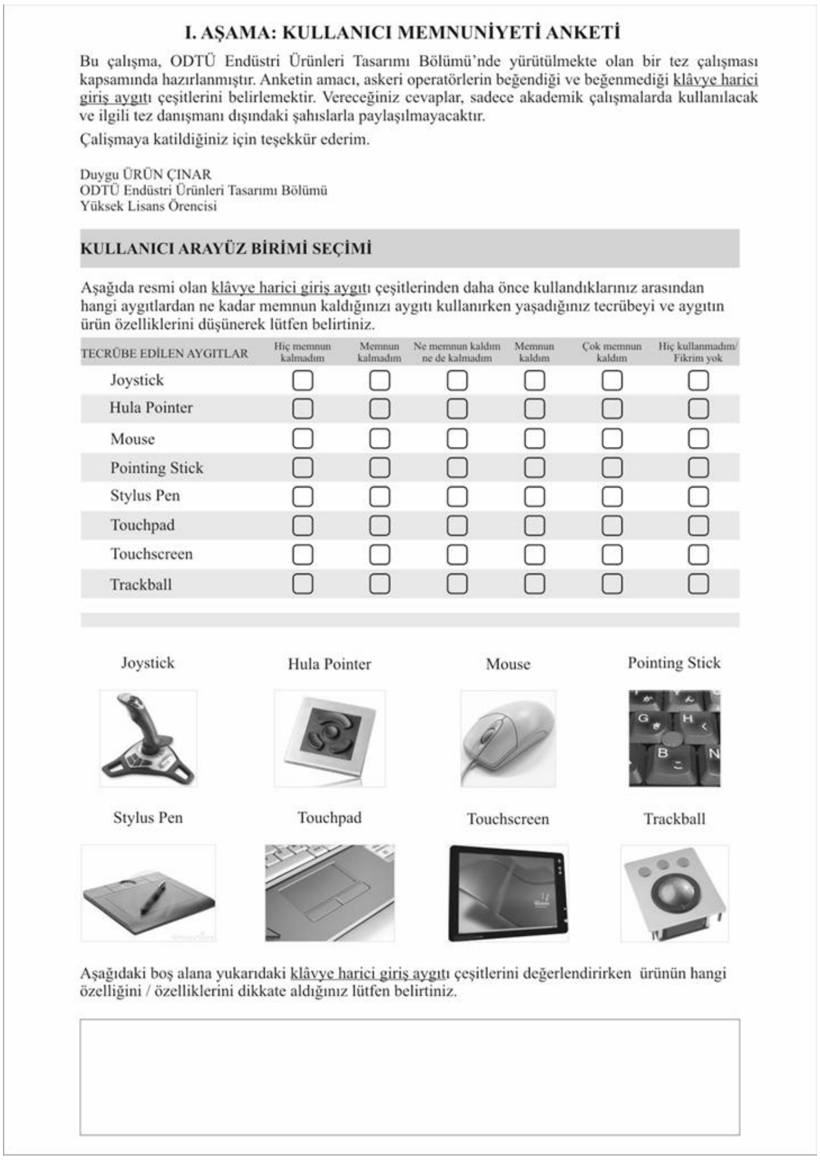
APPENDIX A

PRELIMINARY STUDY QUESTIONNAIRE SHEET



I. AŞAMA: KULLANICI MEMNUNİYETİ ANKETİ

Bu çalışma, ODTÜ Endüstri Ürünleri Tasarımı Bölümü'nde yürütülmekte olan bir tez çalışması kapsamında hazırlanmıştır. Anketin amacı, askeri operatörlerin beğendiği ve beğenmediği klâvye harici giriş aygıtı çeşitlerini belirlemektir. Vereceğiniz cevaplar, sadece akademik çalışmalarda kullanılacak ve ilgili tez danışmanı dışındaki şahıslarla paylaşılmayacaktır.

Çalişmaya katildiğiniz için teşekkür ederim.

Duygu ÜRÜN ÇINAR
ODTÜ Endüstri Ürünleri Tasarımı Bölümü
Yüksek Lisans Örencisi

KULLANICI ARAYÜZ BİRİMİ SEÇİMİ

Aşağıda resmi olan klâvye harici giriş aygıtı çeşitlerinden daha önce kullandıklarınız arasından hangi aygıtlardan ne kadar memnun kaldığınızı aygıtı kullanırken yaşadığınız tecrübeyi ve aygıtın ürün özelliklerini düşünerek lütfen belirtiniz.

TECRÜBE EDİLEN AYGITLAR	Hiç memnun kalmadım	Memnun kalmadım	Ne memnun kaldım ne de kalmadım	Memnun kaldım	Çok memnun kaldım	Hiç kullanmadım/ Fikrim yok
Joystick	☐	☐	☐	☐	☐	☐
Hula Pointer	☐	☐	☐	☐	☐	☐
Mouse	☐	☐	☐	☐	☐	☐
Pointing Stick	☐	☐	☐	☐	☐	☐
Stylus Pen	☐	☐	☐	☐	☐	☐
Touchpad	☐	☐	☐	☐	☐	☐
Touchscreen	☐	☐	☐	☐	☐	☐
Trackball	☐	☐	☐	☐	☐	☐

Joystick
Hula Pointer
Mouse
Pointing Stick
Stylus Pen
Touchpad
Touchscreen
Trackball

Aşağıdaki boş alana yukarıdaki klâvye harici giriş aygıtı çeşitlerini değerlendirirken ürünün hangi özelliğini / özelliklerini dikkate aldığınız lütfen belirtiniz.

Figure A.1 Preliminary Study in Original Language (Turkish)

I. STUDY: USER SATISFACTION QUESTIONNAIRE

This study will be used for the thesis study conducted at the Department of Industrial Design, METU. The aim of the study to determine non-keyboard input devices that operators satisfy and dissatisfy in military. This record will be kept confidential and will not be shared with third persons.

Thank you for your attendance.

Duygu ÜRÜN ÇINAR
ODTÜ Endüstri Ürünleri Tasarımı Bölümü
Graduate Student

DEVICE SELECTION

Please indicate how satisfy or dissatisfy the devices shown in the pictures in relation to experience you have while using them and features of the devices.

DEVICES	very dissatisfied	dissatisfied	neutral	satisfied	very satisfied	never used/ no idea
Joystick	☐	☐	☐	☐	☐	☐
Hula Pointer	☐	☐	☐	☐	☐	☐
Mouse	☐	☐	☐	☐	☐	☐
Pointing Stick	☐	☐	☐	☐	☐	☐
Stylus Pen	☐	☐	☐	☐	☐	☐
Touchpad	☐	☐	☐	☐	☐	☐
Touchscreen	☐	☐	☐	☐	☐	☐
Trackball	☐	☐	☐	☐	☐	☐

Joystick

Hula Pointer

Mouse

Pointing Stick

Stylus Pen

Touchpad

Touchscreen

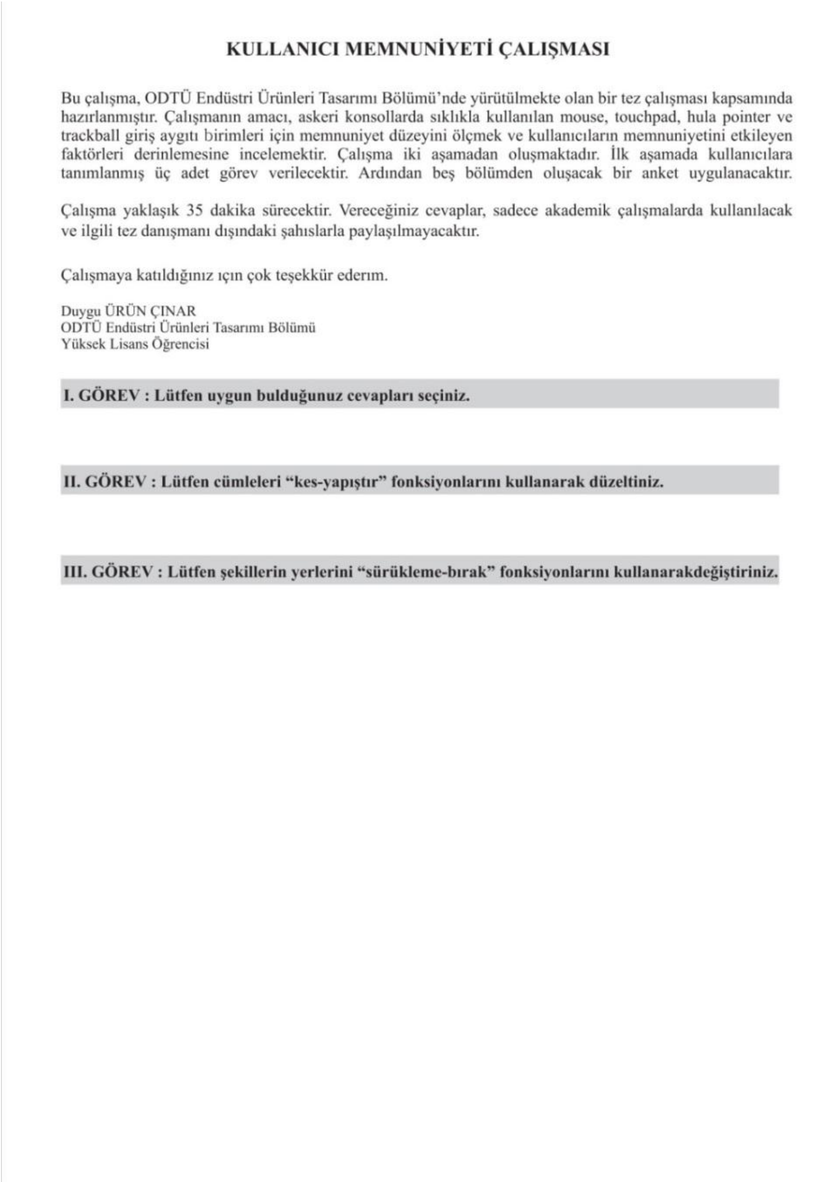
Trackball

Please explain that which product features take into consideration while evaluating the devices above.

Figure A.2 English Translation of Preliminary Study

APPENDIX B

MAIN STUDY QUESTIONNAIRE SHEET



KULLANICI MEMNUNİYETİ ÇALIŞMASI

Bu çalışma, ODTÜ Endüstri Ürünleri Tasarımı Bölümü'nde yürütülmekte olan bir tez çalışması kapsamında hazırlanmıştır. Çalışmanın amacı, askeri konsollarda sıklıkla kullanılan mouse, touchpad, hula pointer ve trackball giriş aygıtı birimleri için memnuniyet düzeyini ölçmek ve kullanıcıların memnuniyetini etkileyen faktörleri derinlemesine incelemektir. Çalışma iki aşamadan oluşmaktadır. İlk aşamada kullanıcılara tanımlanmış üç adet görev verilecektir. Ardından beş bölümden oluşacak bir anket uygulanacaktır.

Çalışma yaklaşık 35 dakika sürecektir. Vereceğiniz cevaplar, sadece akademik çalışmalarda kullanılacak ve ilgili tez danışmanı dışındaki şahıslarla paylaşılmayacaktır.

Çalışmaya katıldığınız için çok teşekkür ederim.

Duygu ÜRÜN ÇINAR
ODTÜ Endüstri Ürünleri Tasarımı Bölümü
Yüksek Lisans Öğrencisi

I. GÖREV : Lütfen uygun bulduğunuz cevapları seçiniz.

II. GÖREV : Lütfen cümleleri "kes-yapıştır" fonksiyonlarını kullanarak düzeltiniz.

III. GÖREV : Lütfen şekillerin yerlerini "sürükleme-bırak" fonksiyonlarını kullanarakdeğiştiriniz.

Figure B.1 Main Study in Original Language (Turkish)

II. AŞAMA: KULLANICI MEMNUNİYETİ ANKETİ

Bu çalışma, ODTÜ Endüstri Ürünleri Tasarımı Bölümü'nde yürütülmekte olan bir tez çalışması kapsamında hazırlanmıştır. Anketin amacı, çalışmanın ilk aşamasında kullandırılan mouse, touchpad, hula pointer ve trackball giriş aygıtı birimleri için kullanıcıların memnuniyet düzeyini ölçmektir.Vereceğiniz cevaplar, sadece akademik çalışmalarda kullanılacak ve ilgili tez danışmanı dışındaki şahıslarla paylaşılmayacaktır.

Çalışmaya katıldığınız ıçin teşekkür ederım.

Duygu ÜRÜN ÇINAR
ODTÜ Endüstri Ürünleri Tasarımı Bölümü
Yüksek Lisans Örencisi

I.KULLANICIYA AİT BİLGİLER

1- Yaşınız nedir?

☐

2- Cinsiyetiniz nedir?

○ Kadın ○ Erkek

3- Hangi elinizi kullanıyorsunuz?

☐ Sağ ☐ Sol

4- Çalıştığınız platform hangisidir?

☐ Hava ☐ Deniz ☐ Kara

5- İşiniz konsol kullanmayı gerektiriyor mu?

☐ Evet ☐ Hayır

Yukarıdaki soruya cevabınız "Hayır" ise,

a) Bundan önceki işlerinizde hiç şelter içerisinde çalıştınız mı?

☐ Evet ☐ Hayır

b) Bundan önceki işlerinizde hiç konsol kullandınız mı?

☐ Evet ☐ Hayır

7- Aralıklarla ya da rutin olarak konsol kullanıyorsanız, bir görev sırasında ortalama kaç saat konsol başında oluyorsunuz?

○ 2-4 ○ 4-6 ○ 6-8 ○ 8-10 ○ 10<

8- Konsol kullanırken bu zamana kadar hangi klavye harici giriş aygıtı çeşit(ler)ini tecrübe ettiniz ?

☐ Mouse ☐ Trackball ☐ Joystick ☐ Touchpad ☐ Diğer :

Figure B.1 (Continued)

II.UYGULAMALI ÇALIŞMANIN DEĞERLENDİRİLMESİ (mouse)

I. Çalışmada tecrübe ettiğiniz "MOUSE" biriminden ne kadar memnun kaldığınızı aşağıdaki cihazın performans ve çalışma şekline dair kriterlere göre lütfen değerlendiriniz.

CIHAZIN PERFORMANSI	Hiç memnun kalmadım	Memnun kalmadım	Ne memnun kaldım ne de kalmadım	Memnun kaldım	Çok memnun kaldım
Beklenildiği şekilde yanıt vermesi					
Benzer görevler için aynı şekilde çalışması					
Yeterli geri bildirim yapması					
Hassaslığın yeterli olması					
Yanıt vermesinin tatmin edici olması					
Kontrol edilebilirliğinin yeterli olması					
Hassas görevlerin yapılmasını sağlaması					
Butonların çalıştırılması için geri bildirim sağlaması					
Çok hassas olmaması					
Doğru seviyede kontrol edilebilirliği					
Ekrandaki bilgilerin kolay seçimi					
İmlecin kolay konumlanması					
İmlecin ekranda kolay gezinmesi					
Rahat çalıştırılması					
Akıcı hareket etmesi					
Hassasiyeti					

II. Çalışmada tecrübe ettiğiniz "MOUSE" cihazını aşağıdaki cihazın çalışma şekli ile ilgili kriterlere göre lütfen değerlendiriniz.

CIHAZIN ÇALIŞMA ŞEKLİ	Hiç uygun değil	Uygun değil	Ne uygun ne uygun değil	Uygun	Çok uygun
Cihazın nasıl çalıştırılacağı açık					
Nasıl çalıştırılacağını anlamak kolay					
Kullanımı kolay					
Hata yapmadı					
Kabul edilebilir çalışma hızı					
Kullanımı karmaşık değil					
Çalıştırmak için düşük efor gerekli					
Kablolar kullanımı engellemedi					
Donanım ve yazılım arasındaki etkileşim yeterlı					

Figure B.1 (Continued)

III. Çalışmada tecrübe ettiğiniz “MOUSE” cihazını aşağıdaki cihazın tasarımı ile ilgili kriterlere göre lütfen değerlendiriniz

CIHAZIN TASARIMI	Hiç uygun değil	Uygun değil	Ne uygun ne uygun değil	Uygun	Çok uygun
Tasarımı kullanıma yönelik olumlu hissettiriyor					
Tasarımı çalışma etkinliğini arttırıyor					
Tutma yüzeyi elin kaymasını önlüyor					
Kolay tutuluyor					
Kolay konumlanıyor					
Hızlı konumlanıyor					
Aşırı çaba harcamadan tutuluyor					
Tasarım yanlış butonlara basılmasını engelliyor					
Butonların şekli parmakların pozisyon almasına yardımcı oluyor					
Butonların şekli butonların çalışmasına yardımcı oluyor					
İstenmeyen imleç hareketlerine neden olmaz					
Cihazın el yapısı ile uyumlu olması					
Cihaz dengeli, kaymaz					
Cihaz ağırlığı kullanılabilirliği etkilemez					
Cihazın boyutu tatmin edici					
Cihazın şekli tatmin edici					
Tüm butonlara ulaşılabiliyor					

IV. Çalışmada tecrübe ettiğiniz “MOUSE” cihazını aşağıdaki cihazın kullanım rahatlığı ile ilgili kriterlere göre lütfen değerlendiriniz.

CIHAZIN KULLANIM RAHATLIĞI	Hiç uygun değil	Uygun değil	Ne uygun ne uygun değil	Uygun	Çok uygun
Baskı noktası oluşturmaz					
Ellerde ters hareketlere neden olmadan kullanılır					
Parmaklarda ters hareketlere neden olmadan kullanılır					
Kolda ters hareketlere neden olmadan kullanılır					
Omuzda ters hareketlere neden olmadan kullanılır					
Başta ters hareketlere neden olmadan kullanılır					
Boyunda ters hareketlere neden olmadan kullanılır					
Parmağı yormaz					
Bileği yormaz					
Kolu yormaz					
Omuzu yormaz					
Boynu yormaz					

Figure B.1 (Continued)

V.Çalışmada kullandığınız giriş aygıtı birimlerinin genel olarak çalışma şeklini lütfen değerlendiriniz.

TECRÜBE EDİLEN BİRİMLER	çok zor	zor	ne zor ne kolay	kolay	Çok kolay
Mouse	☐	☐	☐	☐	☐
Touchpad	☐	☐	☐	☐	☐
Hula Pointer	☐	☐	☐	☐	☐
Trackball	☐	☐	☐	☐	☐

VI.Çalışmada kullandığınız giriş aygıtı birimlerinden genel olarak ne kadar memnun kaldığınızı lütfen belirtiniz.

TECRÜBE EDİLEN BİRİMLER	Hiç memnun kalmadım	Memnun kalmadım	Ne memnun kaldım ne de kalmadım	Memnun kaldım	Çok memnun kaldım
Mouse	☐	☐	☐	☐	☐
Touchpad	☐	☐	☐	☐	☐
Hula Pointer	☐	☐	☐	☐	☐
Trackball	☐	☐	☐	☐	☐

VII.Çalışmada kullandığınız giriş aygıtı birimlerinin genel olarak kullanım rahatlığını lütfen değerlendiriniz.

TECRÜBE EDİLEN BİRİMLER	hiç rahat değil	rahat değil	ne rahat ne rahat değil	rahat	çok rahat
Mouse	☐	☐	☐	☐	☐
Touchpad	☐	☐	☐	☐	☐
Hula Pointer	☐	☐	☐	☐	☐
Trackball	☐	☐	☐	☐	☐

VIII.Çalışmada kullandığınız giriş aygıtı birimlerini çalıştığınız platforma uygunluk derecesine göre lütfen sıralayınız.

TECRÜBE EDİLEN BİRİMLER	Hiç uygun değil	Uygun değil	Ne uygun ne uygun değil	Uygun	Çok uygun
Mouse	☐	☐	☐	☐	☐
Touchpad	☐	☐	☐	☐	☐
Hula Pointer	☐	☐	☐	☐	☐
Trackball	☐	☐	☐	☐	☐

Figure B.1 (Continued)

III.UYGULAMALI ÇALIŞMANIN DEĞERLENDİRİLMESİ

I.Çalışmada kullandığınız giriş aygıtı birimleri için eklemek istediğiniz yorumlar varsa lütfen belirtiniz.

Anketimiz sona ermiştir.
Katıldığınız ve zaman ayırdığınız ıçın teşekkür ederım :)

Figure B.1 (Continued)

APPENDIX C

ENGLISH TRANSLATION OF QUESTIONNAIRE ITEMS

Device Performance
Responds as would expect
Operates in same manner for similar tasks
Adequate feedback
Precision adequate
Responsiveness satisfactory
Adequate control
Allows precision task to be conducted
Feedback provided for button actuation
Not too sensitive
Right level of control
Easy to select information on screen
Easy to place pointer
Easy to move pointer around screen
Comfortable level of force for actuation
Smooth movement
Accurate

Device Operation
Obvious how to operate device
Easy to discover how to operate
Easy to use
Did not make mistakes
Acceptable operation speed
Not complicated to use
Low effort required to operate
Cables do not interfere with movement
Adequate interaction between hard and software

Device Design
Design makes me feel positive towards use
Device design enhances its operation
Grip surface prevents slipping
Grasped easily
Can be positioned easily
Can be positioned quickly
Held without excessive effort
Design prevents inadvertent button activation
Shape of button assists finger positioning
Shape of button assists button actuation
Does not cause unintended pointer movement
Device accommodates hand size
Device is stable, does not slip/rock
Device weight does not impair usability
Satisfactory size
Satisfactory shape
Could reach all buttons

Device Comfort
Does not cause pressure points
Used without deviations of hand
Used without deviations of fingers
Used without deviations of arm
Used without deviations of shoulder
Used without deviations of head
Used without deviations of neck
No finger fatigue
No wrist fatigue
No arm fatigue
No shoulder fatigue
No neck fatigue

Subjective Comments

Overall rating (very satisfied/satisfied)

Overall operation (very easy/easy to use)

General comfort (very comfortable/comfortable)

Figure C.1 English Translation of Main Study

APPENDIX D

SPSS RESULTS OF PRELIMINARY STUDY

Table D.1 SPSS Descriptive Statistics & Frequency Tables of Preliminary Study

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
joystick	50	1,00	5,00	3,3600	1,30556
hulapointer	14	1,00	5,00	2,4286	1,28388
mouse	48	1,00	5,00	4,4167	,70961
touchpad	44	1,00	5,00	2,1818	1,06253
touchscreen	17	1,00	5,00	3,5882	,87026
pointingstick	49	1,00	5,00	3,2653	1,15064
trackball	50	1,00	5,00	4,3600	,98478
styluspen	32	1,00	5,00	2,8125	1,25563
Valid N (listwise)	8				

Cross Tables

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
joystick * kullanicinin calistigi platform	50	98,0%	1	2,0%	51	100,0%
hulapointer * kullanicinin calistigi platform	14	27,5%	37	72,5%	51	100,0%
mouse * kullanicinin calistigi platform	48	94,1%	3	5,9%	51	100,0%
touchpad * kullanicinin calistigi platform	44	86,3%	7	13,7%	51	100,0%
touchscreen * kullanicinin calistigi platform	17	33,3%	34	66,7%	51	100,0%
pointingstick * kullanicinin calistigi platform	49	96,1%	2	3,9%	51	100,0%
trackball * kullanicinin calistigi platform	50	98,0%	1	2,0%	51	100,0%
styluspen * kullanicinin calistigi platform	32	62,7%	19	37,3%	51	100,0%

Compare the Means

kullanicinin		joystick	hulapointer	mouse	touchpad	touchscreen	pointingstick	trackball	styluspen
kara	Mean	3,5294	2,0000	4,4375	2,2500	3,7143	3,3529	4,5882	2,6667
	N	17	5	16	16	7	17	17	9
	Std. Deviation	1,32842	1,00000	,51235	1,00000	,48795	,93148	,87026	1,41421
	% of Total N	34,0%	35,7%	33,3%	36,4%	41,2%	34,7%	34,0%	28,1%
	% of Total Sum	35,7%	29,4%	33,5%	37,5%	42,6%	35,6%	35,8%	26,7%
deniz	Mean	3,3125	3,0000	4,2000	2,3571	3,6000	3,4667	3,8750	3,2000
	N	16	7	15	14	5	15	16	15
	Std. Deviation	1,44770	1,41421	1,01419	1,39268	1,51658	1,45733	1,25831	1,20712
	% of Total N	32,0%	50,0%	31,3%	31,8%	29,4%	30,6%	32,0%	46,9%
	% of Total Sum	31,5%	61,8%	29,7%	34,4%	29,5%	32,5%	28,4%	53,3%
hava	Mean	3,2353	1,5000	4,5882	1,9286	3,4000	3,0000	4,5882	2,2500
	N	17	2	17	14	5	17	17	8
	Std. Deviation	1,20049	,70711	,50730	,73005	,54772	1,06066	,61835	1,03510
	% of Total N	34,0%	14,3%	35,4%	31,8%	29,4%	34,7%	34,0%	25,0%
	% of Total Sum	32,7%	8,8%	36,8%	28,1%	27,9%	31,9%	35,8%	20,0%
Total	Mean	3,3600	2,4286	4,4167	2,1818	3,5882	3,2653	4,3600	2,8125
	N	50	14	48	44	17	49	50	32
	Std. Deviation	1,30556	1,28388	,70961	1,06253	,87026	1,15064	,98478	1,25563
	% of Total N	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
	% of Total Sum	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

Table D.1 (Continued)

Frequency Tables

joystick

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	hicmemnun kalmadim	9	17,6	18,0	18,0
	memnunkalmadim	1	2,0	2,0	20,0
	nememnunkaldimnek almadim	11	21,6	22,0	42,0
	memnunkaldim	21	41,2	42,0	84,0
	cokmemnunkaldim	8	15,7	16,0	100,0
	Total	50	98,0	100,0	
Missing	System	1	2,0		
Total		51	100,0		

hulapointer

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	hicmemnun kalmadim	4	7,8	28,6	28,6
	memnunkalmadim	4	7,8	28,6	57,1
	nememnunkaldimnek almadim	3	5,9	21,4	78,6
	memnunkaldim	2	3,9	14,3	92,9
	cokmemnunkaldim	1	2,0	7,1	100,0
	Total	14	27,5	100,0	
Missing	System	37	72,5		
Total		51	100,0		

mouse

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	hicmemnun kalmadim	1	2,0	2,1	2,1
	memnunkaldim	24	47,1	50,0	52,1
	cokmemnunkaldim	23	45,1	47,9	100,0
	Total	48	94,1	100,0	
Missing	System	3	5,9		
Total		51	100,0		

touchpad

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	hicmemnun kalmadim	13	25,5	29,5	29,5
	memnunkalmadim	17	33,3	38,6	68,2
	nememnunkaldimnek almadim	8	15,7	18,2	86,4
	memnunkaldim	5	9,8	11,4	97,7
	cokmemnunkaldim	1	2,0	2,3	100,0
	Total	44	86,3	100,0	
Missing	System	7	13,7		
Total		51	100,0		

Table D.1 (Continued)

Frequency Tables

trackball

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	hicmemnun kalmadim	1	2,0	2,0	2,0
	memnunkalmadim	3	5,9	6,0	8,0
	nememnunkaldimnek almadim	3	5,9	6,0	14,0
	memnunkaldim	13	25,5	26,0	40,0
	cokmemnunkaldim	30	58,8	60,0	100,0
	Total	50	98,0	100,0	
Missing	System	1	2,0		
Total		51	100,0		

styluspen

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	hicmemnun kalmadim	4	7,8	12,5	12,5
	memnunkalmadim	12	23,5	37,5	50,0
	nememnunkaldimnek almadim	6	11,8	18,8	68,8
	memnunkaldim	6	11,8	18,8	87,5
	cokmemnunkaldim	4	7,8	12,5	100,0
	Total	32	62,7	100,0	
Missing	System	19	37,3		
Total		51	100,0		

touchscreen

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	hicmemnun kalmadim	1	2,0	5,9	5,9
	nememnunkaldimnek almadim	5	9,8	29,4	35,3
	memnunkaldim	10	19,6	58,8	94,1
	cokmemnunkaldim	1	2,0	5,9	100,0
	Total	17	33,3	100,0	
Missing	System	34	66,7		
Total		51	100,0		

pointingstick

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	hicmemnun kalmadim	4	7,8	8,2	8,2
	memnunkalmadim	9	17,6	18,4	26,5
	nememnunkaldimnek almadim	12	23,5	24,5	51,0
	memnunkaldim	18	35,3	36,7	87,8
	cokmemnunkaldim	6	11,8	12,2	100,0
	Total	49	96,1	100,0	
Missing	System	2	3,9		
Total		51	100,0		

APPENDIX E

DATA ANALYSIS SAMPLE OF PRELIMINARY STUDY

Table E.1 Thematic Coding Sample of Preliminary Study

	A	B	C	D	E
1					
2	pratik olması	2		kolay kullanım	3
3	performans	2		basit	3
4	hassaslık	1		çalışma şekli	2
5	hızlı tepki	6		cihazın kolay çalışması	1
6					
7	tutuş rahatlığı	3		konfor	4
8	cihaz tasarımı	1		eli ağrıtmaması	1
9	elden kayması	1			
10	butonlara kolay ulaşım	1			
11					
12				esneklik	1
13				sağlamlık	1
14				sızdırmazlık	1
15					
16					
17					
18					
19					
20					

APPENDIX F

SAMPLE OF CORRELATION ANALYSIS RESULTS

Table F.1 Correlation Analysis Sample

Correlations

		S1	S2	S3	S4	S5	S6
S1	Pearson Correlation	1	,894**	,927**	,881**	,897**	,868**
	Sig. (2-tailed)		,000	,000	,000	,000	,000
	N	84	84	84	84	84	84
S2	Pearson Correlation	,894**	1	,891**	,822**	,859**	,820**
	Sig. (2-tailed)	,000		,000	,000	,000	,000
	N	84	84	84	84	84	84
S3	Pearson Correlation	,927**	,891**	1	,909**	,949**	,866**
	Sig. (2-tailed)	,000	,000		,000	,000	,000
	N	84	84	84	84	84	84
S4	Pearson Correlation	,881**	,822**	,909**	1	,902**	,869**
	Sig. (2-tailed)	,000	,000	,000		,000	,000
	N	84	84	84	84	84	84
S5	Pearson Correlation	,897**	,859**	,949**	,902**	1	,885**
	Sig. (2-tailed)	,000	,000	,000	,000		,000
	N	84	84	84	84	84	84
S6	Pearson Correlation	,868**	,820**	,866**	,869**	,885**	1
	Sig. (2-tailed)	,000	,000	,000	,000	,000	
	N	84	84	84	84	84	84
S7	Pearson Correlation	,826**	,854**	,836**	,868**	,847**	,889**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000
	N	84	84	84	84	84	84
S8	Pearson Correlation	,763**	,840**	,806**	,757**	,784**	,766**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000
	N	84	84	84	84	84	84
S9	Pearson Correlation	,739**	,676**	,745**	,745**	,767**	,736**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000
	N	84	84	84	84	84	84
S10	Pearson Correlation	,880**	,819**	,866**	,868**	,921**	,897**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000
	N	84	84	84	84	84	84
S11	Pearson Correlation	,868**	,811**	,871**	,843**	,925**	,857**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000
	N	84	84	84	84	84	84
S12	Pearson Correlation	,825**	,731**	,810**	,848**	,863**	,823**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000
	N	84	84	84	84	84	84
S13	Pearson Correlation	,832**	,742**	,806**	,790**	,820**	,796**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000
	N	84	84	84	84	84	84
S14	Pearson Correlation	,855**	,776**	,826**	,791**	,839**	,815**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000
	N	84	84	84	84	84	84
S15	Pearson Correlation	,760**	,690**	,780**	,813**	,832**	,753**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000
	N	84	84	84	84	84	84
S16	Pearson Correlation	,668**	,577**	,681**	,728**	,752**	,703**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000
	N	84	84	84	84	84	84

APPENDIX G

SPSS-ANOVA RESULTS OF MAIN STUDY QUESTIONNAIRE

Table G.1 Multivariate Test Results of SPSS for Main Study

Multivariate Tests[c] 1-54

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	,975	13,711[a]	54,000	19,000	,000
	Wilks' Lambda	,025	13,711[a]	54,000	19,000	,000
	Hotelling's Trace	38,968	13,711[a]	54,000	19,000	,000
	Roy's Largest Root	38,968	13,711[a]	54,000	19,000	,000
platform	Pillai's Trace	1,601	1,484	108,000	40,000	,079
	Wilks' Lambda	,026	1,833[a]	108,000	38,000	,018
	Hotelling's Trace	13,395	2,233	108,000	36,000	,004
	Roy's Largest Root	11,249	4,166[b]	54,000	20,000	,000
cihaz	Pillai's Trace	2,361	1,438	162,000	63,000	,050
	Wilks' Lambda	,007	1,509	162,000	57,895	,036
	Hotelling's Trace	14,344	1,564	162,000	53,000	,030
	Roy's Largest Root	8,106	3,152[b]	54,000	21,000	,003
platform * cihaz	Pillai's Trace	4,339	1,161	324,000	144,000	,152
	Wilks' Lambda	,000	1,161	324,000	122,492	,169
	Hotelling's Trace	21,340	1,142	324,000	104,000	,214
	Roy's Largest Root	7,468	3,319[b]	54,000	24,000	,001

Tests of Between-Subjects Effects 55-58

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	S55	92,417[a]	11	8,402	6,942	,000
	S56	73,464[b]	11	6,679	5,178	,000
	S57	77,571[c]	11	7,052	4,950	,000
	S58	79,286[c]	11	7,208	4,949	,000
Intercept	S55	913,440	1	913,440	754,711	,000
	S56	926,679	1	926,679	718,532	,000
	S57	867,857	1	867,857	609,192	,000
	S58	867,857	1	867,857	595,913	,000
platform	S55	,667	2	,333	,275	,760
	S56	,929	2	,464	,360	,699
	S57	1,143	2	,571	,401	,671
	S58	,643	2	,321	,221	,002
cihaz	S55	60,607	3	20,202	16,692	,000
	S56	41,560	3	13,853	10,742	,000
	S57	47,095	3	15,698	11,019	,000
	S58	28,048	3	9,349	6,420	,001
platform * cihaz	S55	31,143	6	5,190	4,289	,001
	S56	30,976	6	5,163	4,003	,002
	S57	29,333	6	4,889	3,432	,005
	S58	50,595	6	8,433	5,790	,000
Error	S55	87,143	72	1,210		
	S56	92,857	72	1,290		
	S57	102,571	72	1,425		
	S58	104,857	72	1,456		
Total	S55	1093,000	84			
	S56	1093,000	84			
	S57	1048,000	84			
	S58	1052,000	84			
Corrected Total	S55	179,560	83			
	S56	166,321	83			
	S57	180,143	83			
	S58	184,143	83			

a. R Squared = ,515 (Adjusted R Squared = ,441)

b. R Squared = ,442 (Adjusted R Squared = ,356)

APPENDIX H

DATA ANALYSIS SAMPLE OF FOCUS GROUP DISCUSSION

Table H.1 Thematic Coding Sample of Focus Group

E	F	G	H	I
	Design			
AIR	MOUSE	TOUCHPAD	HULA POINTER	TRACKBALL
	CİHAZIN FORMU VE BÜYÜKLÜĞÜ (2)	CİHAZIN FORMU VE BÜYÜKLÜĞÜ (1)	CİHAZIN MALZEMESİ (S&H-4)	CİHAZIN MALZEMESİ (SIZDIRMAZLIK & HİJYEN-4)
			CİHAZIN FORMU VE BÜYÜKLÜĞÜ (2)	BUTONLARIN YERİ (3)
			BUTONLARIN YERİ (1)	CİHAZIN FORMU VE BÜYÜKLÜĞÜ (2)
LAND	MONTAJI (safety) (3)	CİHAZIN FORMU VE BÜYÜKLÜĞÜ (1)	CİHAZIN TUTMA YERİ (5)	DAYANIKLILIK (2)
	CİHAZIN FORMU VE BÜYÜKLÜĞÜ (2)		CİHAZIN MALZEMESİ (S&H-4)	CİHAZIN FORMU VE BÜYÜKLÜĞÜ (3)
	CİHAZIN AĞIRLIĞI (1)		BUTONLARIN FORMU VE BÜYÜKLÜĞÜ (2)	BUTONLARIN YERİ (1)
	CİHAZIN TUTMA YÜZEYİ (1)		CİHAZIN TUTMA YÜZEYİ (2)	BUTONLARIN FORMU VE BÜYÜKLÜĞÜ (1)
				CİHAZIN MALZEMESİ (SIZDIRMAZLIK & HİJYEN-1)
NAVY	MONTAJI (5)	BUTONLARIN YERİ (1)	CİHAZIN MALZEMESİ (S&H-3)	CİHAZIN FORMU VE BÜYÜKLÜĞÜ (2)
	CİHAZIN FORMU VE BÜYÜKLÜĞÜ (2)	DAYANIKLILIK (2)	CİHAZIN FORMU VE BÜYÜKLÜĞÜ (2)	BUTONLARIN YERİ (1)
	BUTONLARIN FORMU VE BÜYÜKLÜĞÜ (1)		DAYANIKLILIK (2)	CİHAZIN MALZEMESİ (SIZDIRMAZLIK & HİJYEN-1)