VISUALLY-IMPAIRED USERS AND PRODUCT INTERACTION: A STUDY ON THE INTERFACES OF WASHING MACHINES, VACUUM CLEANERS AND IRONS

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ABSTRACT

VISUALLY-IMPAIRED USERS AND PRODUCT INTERACTION:
A STUDY ON THE INTERFACES OF WASHING MACHINES, VACUUM CLEANERS AND IRONS

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The appearance of the electrical appliances has undergone a dramatic change in many aspects since the 1920's. Throughout years, along with their changed appearance, the way the appliances are perceived has altered. The interface of domestic products is mainly dominated by visual elements. Undoubtedly, the domination of the visual perception in the interfaces of the appliances might cause complications in the interaction between the product and visually impaired users.

In this thesis, the interaction between the electrical household appliances and visually impaired user is examined to identify the strong points in the interaction as well as any complications that may occur during the interaction. Observations were conducted with ten users to explore the interaction between the visually impaired users and three electrical domestic appliances: washing machine, vacuum cleaner and iron.

The findings of the observations indicate that visually impaired users can operate their appliances, with some limitations. Yet a number of common problematic points related to the interface elements, which hinder from using their electrical appliances with full functionality, were encountered. At the end of the study, a list of design recommendations, some of which offered in the literature previously, are suggested.

Keywords: Visually Impaired User, Product Interaction, Product Interface, Electrical Consumer Products.

ÖZ

GÖRME ENGELLİ KULLANCI VE ÜRÜN ETKİLEŞİMİ:
ÇAMAŞIR MAKİNESİ, ELEKTRİKLİ SÜPÜRGE VE ÜTÜ ARAYÜZLERİ ÜZERİNE BİR ÇALIŞMA

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Elektrikli ev aletleri 1920'lerden beri bir çok açıdan bir değişimin içerisindedir. 1920'lerden günümüze kadar, elektrikli ev aletlerinin görünümünün değişmesiyle beraber algılanış biçimleri de değişmiştir. Tüketici ürünlerinin arayüzlerinde hakimiyet görsel arayüz elemanlarındadır. Şüphesiz, görsel algının ev aletlerinin arayüzlerinin algılanmasında ön planda olması ürün ve görme engelli kullanıcı arasındaki etkileşimde sorunlara yol açabilmektedir.

Bu çalışmada, görme engelli kullancı ve elektrikli ev aletleri arasındaki etkileşim incelenmektedir ve bu etkileşimde sorunlu yanlarla beraber, güçlü yanlarında tanımlanması amaçlanmaktadır. Bu amaçla, 10 kullanıcıyla gerçekleştirilen gözlemlerde, görme engelli kullanıcı ve üç elektrikli ev aleti; çamaşır makinesi, elektrikli süpürge ve ütü, arasındaki etkileşim araştırılmıştır.

Gözlemlerden elde edilen bulgular, görme engelli kullanıcıların bu elektrikli ev aletlerini bazı eksiklik ve kısıtlamalarla kullanabildiklerini göstermektedir. Buna karşın, kullanıcının ürünü bütün fonksiyonlarıyla kullanmasına engel olan arayüz elemalarıyla ilgili olarak bir takım sorunlu noktalarla karşılaşıldı.

Çalışmanın sonucunda, bazıları literatür çalışmasında da elde edilmiş olan, tasarım önerileri ortaya konuldu.

Anahtar Kelimeler: Görme Engelli Kullanıcı, Ürün Etkileşimi, Ürün Arayüzü, Elektrikli Tüketici Ürünleri.

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CHAPTER I

INTRODUCTION

1.1. PROBLEM STATEMENT

Electrical appliances began to appear in homes following the end of World War I. In the post-war years, manufacturers turned their attention from military material to consumer products (Meikle, 1993). The radio, which had been used as military equipment during the war, was the first consumer product introduced to households (Brenni, 1991).

In 1920's, consumers believed that the visible mechanical parts of appliances were the indicators that the product had high technical specifications. Therefore, the technical look became the major factor which made the product different and more desirable to the consumer (Brenni, 1991). In the late 1920's, due to the competition, manufacturers began to seek different methods and approaches to have a market advantage. Consequently, design gained importance as it added value to the product. After this point, the forms of the electrical appliances changed and varied. However, the physical dimensions of the appliances were determined by the mechanism inside it.

In the 1950's, the bond between the form and function loosened as electrical products underwent miniaturization, allowed by the introduction of the transistor. The technical appearance of the 1920's projected to the 1950's as a scientific look with closed, rounded-corner boxes and membrane switches (Brenni, 1991). The concerns the consumers and the manufacturers had about the high technical specifications of the product were replaced with the concerns about the product being visually appealing.

After 1990's, miniaturization permitted by the microchip development made it possible to place a large quantity of elements for controlling different and complex functions on the same interface panel. The products which already have been used by majority underwent a shift in terms of form and functionality of the product. For instance, telephones became smaller in size and bigger in capability.

If we approach the interface of consumer appliances in the context of perception, there are three kinds of sensations through which we perceive the interface. These sensations are visual, auditory and haptic/tactile. It is possible to say an interface is a composition of these three different perceptions. Today, with technologic implementations, the ratio of the visual

elements in the composition has been on the rise. Because the attention and the interest are focused on the visual attractiveness of products, the interfaces designed also rely heavily on visual perception.

The interfaces, with their relatively high number of visual control elements, do not cause a complication for users who do not have any trouble with their senses. However, from the aspect of users who do not have visual perception, these products are not perceivable at all.

If a person has visual impairment, but no other physical impairments such as a gripping problem or a cognitive disability, they are capable of full comprehension by using their other senses. Therefore, if such a person fails to operate the product, the reason of this failure is solely because they can not perceive the product. In other words, the interaction process with the product is broken.

1.1.1. Aim of the Thesis

The aim of the thesis is to understand the interaction between the visually-impaired user and electrical appliances. Accordingly, the study carried out in the thesis is expected to identify the strong points in the interaction as well as any complications that may occur during the interaction. Three factors determine the scope of the study:

The product group

An electrical consumer product is obviously the extension of a technologic progress, brought into our homes. Today, electrical appliances are an important part of every household. It is possible to come across some common appliances in any home and it is assumed that everyone is capable of handling these appliances.

This study examines the relationship between the electrical appliances and the visually-impaired users in terms of problematic points while handling these appliances.

The interface

In the context of the study, the interface is a medium that enables interaction between the product and the user. In this concept, the interface is considered as the skin of the product that includes any part or surface that allows interaction with the user. Similar to a common control panel on a washing machine, the hose of a vacuum cleaner also allows interaction with the user and can be considered to be a component of interface of the vacuum cleaner. Visually-impaired user can benefit from the hose as a reference point to find the other controls. Likewise, the electrical cable of the product would also be regarded as an interface

component through which the visually-impaired user interacts with the appliance. Plugging is one of the steps of the task when running an electrical appliance. On the contrary of sighted users, visually-impaired users may spend a considerable time at the step of plugging. In addition, the electrical cable, for visually-impaired person, may also be the possible reason of an accident. Users may trip over the electrical cord accidentally.

The user group

As mentioned above, the user group this study focuses on is persons who have visual impairment. The term “impairment” is preferred rather than handicap because handicap may refer to a disability caused by some external physical barrier such as an obstacle which makes it impossible to see. The term disability is not used due to concern about the various degrees of blindness, which are going to be explained in further detail in the following sections under this chapter. The number of people who can not see at all, who are completely unable to sense the presence or absence of light, is actually much lower than commonly believed. People who are often called as visually-impaired frequently only have different levels of vision defect. (Vanderheiden, 1987)

1.1.2. Research Questions

As Asatekin (1997) states, in the man-machine interaction there are two points that need to be satisfied so that the process of interaction is accomplished successfully:

Does the product fulfill its functions adequately?

When functioning, is the communication between the product and the user satisfactory?

As emphasized previously, in the interaction process, the perception of interface basically relies on the visual sensation. Accordingly, the question “How does interaction between a visually-impaired user and a product depending on visual clues to operate takes place?” comes to mind. From this point, with respect to the previous questions, two more questions can be derived:

Does the user who has visual impairment utilize the product with full functionality?

What kind of communication occurs between the product, and the user with visual impairment and what are the weak points in this communication?

Furthermore, another question might be added with the purpose of understanding how a user reacts to possible problems:

Can the user compensate for and recover if there is a break in the communication loop?

At the end of the thesis, it is expected to find answers to these questions. After the problematic points that may cause the break down of the interaction process between the visually-impaired user and the machine are determined, design suggestions will be given to minimize the effect of complications that may arise during operation.

1.1.3. Structure of the Thesis

Understanding the context of the problem at different stages is the main theme of the first three chapters. The last chapter is a synthesis of the findings of previous chapters and forms a conclusion to the study.

The introduction chapter is concerned with understanding the problem and where the visually-impaired user stands in the context of disability.

The second chapter focuses on the theories that describe the user-product relation. This section involves literature research on the interface of electrical consumer products and interaction between the user and the product aims to build a base for the third chapter.

The third chapter aims to understand the interaction of users with visual impairments with electrical appliances. Observation is the method of the research used to obtain information on interaction that can not be obtained from literature research and any problems that come up during the usage of the appliance. This chapter consists of three tests, each forming a section of the chapter. An evaluation of the test is available at the end of each section.

The fourth and final chapter contains an evaluation of all products in terms of components of interfaces. The evaluation consists of an analysis of problematic points revealed in the test and design suggestions aimed to address these issues.

1.2. DESIGN AND DISABILITY

1.2.1. Disability: A Functional Limitation

Visual impairment is a kind of disability. Disabilities, which a significant portion of the world population has to live with, has been the subject of many different studies, performed by people from different fields and professions such as social studies or computer industry, as well as the practice of design. However, a common definition of disability or a common identification of who constitutes a disabled person has not been reached yet. It can be said

that if a person perceives herself as someone with a disability, she is a disabled person (Mackelprang and Salsgiver, 1999).

A disability is the situation of functional limitation that is caused by some particular impairment. Disabilities may be grouped according to the type of impairment. In the literature, there are various types of approaches to the classification of impairments. Yet, these approaches to the types of Impairments can be summarized under four broad and common titles:

Visual Impairments
Hearing Impairments
Physical Impairments
Cognitive Impairments

While the first two impairments, visual and hearing, do not have any subgroups; physical and cognitive impairments can be further divided. For instance, Mackelprang and Salsgiver (1999) examine cognitive disabilities under three subgroups: developmental disabilities, psychiatric disabilities and cognitive disabilities.

The recent approaches to the classification of disability have been radically changed. The World Health Organization (WHO) states that ability is not a permanent situation; it is a variable that can change throughout the life. An individual may fall in a category that may be called a disability any time. Hence, disabilities should not be categorized in respect to the limitations of functions. Therefore, WHO proposes a new system which is called the International Classification of Function (ICF) (Adaptive Environments Organization, 2006). As its name implies, the ICF is based on functional status. People are evaluated in terms of their functional status. Ability is used rather than disability, because it covers the description of health related states. In addition, the ICF describes the body functions instead of disabilities. Accordingly, the ICF defines the impairment as problem in body functions or structure as a significant deviation or loss (Johnston, 2003).

1.2.1.1. Visual Impairments

Definition of visual disability is vague and to some extent, a subjective matter. Contrary to the common belief, visual impairment does not mean total blindness; the term may include some level of vision or other impairments called as low vision such as haziness, film over eye, foggy vision (Vanderheiden, 1987). In fact, a person with visual disability may have visual sense to a certain extent. In this study, the term impairment is used instead of the term disability to avoid the common misconceptions about the term disability.

As has been noted, visual impairment covers a range from very poor vision to perception of light without seeing any shapes to the total lack of light perception. Nevertheless, in general discussion, visual impairment can be examined under two main categories: Legal blindness and low vision (Vanderheiden and Vanderheiden, 1991). Medically, a person is defined as legally blind if his visual acuity is 20/200[1] or worse with the best correction. Legally-blind people may still retain some perception of shape and light. A person is considered as visually impaired if his vision acuity is 20/80 or worse with the best correction.

Visual impairments may be caused defects or diseases of the visual system some of them appear after the first years of life. Moreover, there are many diseases such as cataracts, glaucoma and diabetic retinopathy, that are related to aging which may cause visual impairments.

Visual impairment may be resulted in several problems such as dimness of vision, haziness, film over the eye, foggy vision, extreme near or farsightedness, distortion of vision, double vision, spots before the eyes, color distortions, visual field defects, tunnel vision, no peripheral vision, abnormal sensitivity to light or glare and night blindness.

1.2.1.2. Hearing Impairments

Individuals with hearing disabilities can be totally deaf or be hard-of-hearing (Mackelprang and Salsgiver, 1999). Deafness expresses an extreme situation of hearing loss. A person who is defined as deaf needs at least 90 decibels to hear. Lesser degrees of hearing impairment are called hard-of-hearing (Schein, 1981; cited in Vanderheiden and Vanderheiden, 1991). Hearing impairment is divided into three subgroups according to where the loss of function occurs in the hearing mechanism. Each subgroup contains a range of hearing impairment from mild hearing loss to profound hearing loss.

Conductive hearing loss is caused by the damage in the middle ear mechanism that conducts sound.

Sensorial hearing loss results from damage to the auditory pathways in the inner ear.

Central hearing loss is rare and is caused by problems in the brain such as multiple sclerosis, cerebrovascular disease or tumor (Mackelprang and Salsgiver, 1999).

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[1] Today, in determining the visual acuity (sharpness of vision) is used a chart that was developed by Dr. Herman Snellen. With the chart based on nine lines of letters, visual acuity is determined as a fraction. In this fraction, 20/20 is assumed as “normal”. A person whose vision acuity is 20/200 sees at 20 feet what the normal eye can at 200 feet.

1.2.1.3. Physical Impairments

Physical impairments can be examined under two categories as neuromuscular and skeletal impairments according to the origin. (C/O Trace R & D Center, 2006).

Neuromuscular impairments include diseases such as paralysis and muscular dystrophy. Skeletal impairments include diseases in the joints, undeveloped limbs or completely missing limbs. Some major diseases that cause physical impairments are Parkinson's disease, cerebral palsy (CP), arthritis, loss of limbs or digits (amputation or congenital) and stroke (cerebral vascular accident; CVA).

1.2.1.4. Cognitive Impairments

There are three types of cognitive impairment:

Mental impairments are caused by down syndrome and premature birth and damage to the brain before or after birth. An individual with a mental impairment generally has an IQ below 70.

Language and learning disabilities result from brain damage. The individual who has learning and language disabilities can not understand the patterns of language. Although they may have problems in speaking and writing, these individuals may have a high level intelligence.

Age-related impairments are results of the age-related diseases such as Alzheimer and dementia. They cause decrease in mental functions like loss of memory and lapses in judgment. (C/O Trace R & D Center, 2006).

1.2.2. Disability and Design Practice

The movement against the institutionalization of disabled and the legislations regarding rights of disabled causes a degree of social awareness. Once, the disabled people were seen as a minority who may be ignored in the society. However, with the help of legislations such as Americans with Disabilities Act (1990) the disabled have begun to acquire a positive identity.

In reality, the disability rights movement alone did not make people realize the importance of the issue. The factor that affected the disabled most is technological advancements. Technological advancements had impacts in two-opposite directions: First, the innovations such as the Internet and virtual reality, leading to access to digital information exclude the

disabled. However, the technological advancements might also be used for the benefit of the disabled to include them into the rest of society. On the other hand, for a few years, PC and internet usage by persons with sensory impairment such as visually and hearing became widespread due to the advancements in computer industry regarding the accessibility of the disabled.

The motto; “right of access to information” rises under the influence of technologic innovations, as the way to reach information changes.

Haigh (1993; cited in Coleman, 2003) regard people with disabilities and the elderly similarly. Some kinds of disabilities such as visual, hearing and physical impairments may appear with old age. Thus, it could be said that disability is a situation. Everyone might be in this situation, not only in old age, but also in any age due to an accident or a disease. This claim is one of the premises of disability discussions. The movement of independent living defends the elderly and the disabled should be able to live independently. The manifesto of the movement is that the elderly and the disabled people have a right to live without depending on somebody, something or someplace just like the rest of the society.

Altering the way of seeing disability and the disabled directly affected the expectations about life standards of the disabled people. Living as “normal” as other people requires some indications in practical, everyday life. Accordingly, several approaches whose basis might be similar or completely different are advocated.

1.2.2.1. Design Approaches to Disability

Although the approaches to design for the needs of the disabled share similar bases; there are two opposite points of view. The first point of view argues that design must satisfy the needs of all people, including individuals with disabilities (Mace, 1991; cited in Story and Mueller, 2001). The second point of view supports making designs for specific user groups, such as users with visual disabilities or mobility disabilities (Vanderheiden, 1987). Apart from these extreme views, there are moderate opinions that claim a product should be designed in a way to embrace as many users as possible. Despite many of the approaches are different approaches; their bases are similar to each other and might overlap.

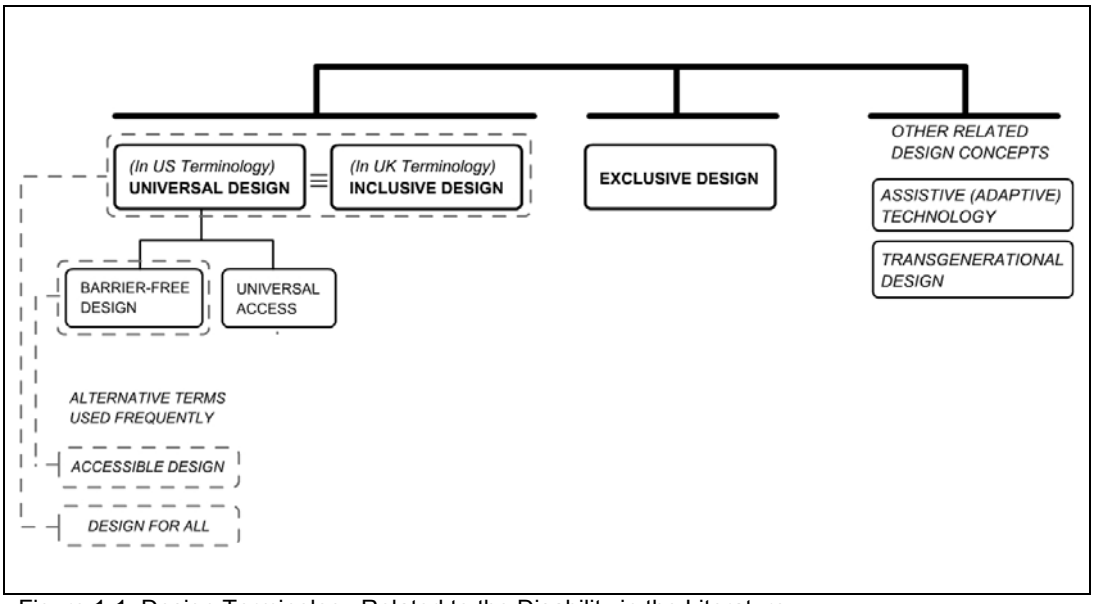

Figure 1-1: Design Terminology Related to the Disability in the Literature

Figure 1-1 summarizes the different terms encountered during the literature review. In the figure, two main opposite approaches to the design for disabled: inclusive design and exclusive design. Terminology shows differences according to the context and origin of the term. Aside from two opposite ends, there are different concepts such as assistive technology and transgenerational design. Their scopes are slightly out of the main streams.

Universal Design and Inclusive Design

"Desk research showed almost identical definitions and conclusions in American discussions of 'universal design' and 'accessibility' and European ones on 'barrier free design', 'usability', and 'Design for All'. All agree upon the American Trace Center definition of 'universal design'. This normative concept implies that designers have to look at a person with a disability just as they look at any other person." (European Commission, 1998)

In spite of the differences in the definitions of the universal design and inclusive design, generally, universal design and inclusive design refer to the same set of goals. While the term of universal design comes from US terminology, inclusive design is an approach that emerged in the UK. Hence, it would be suitable to define both under the same title (Figure 1-1).

Universal design and inclusive design can both be defined as a design approach that ensures all products, environments and services can be used by as many people as possible irrespective of age or ability (NC State University, The Center for Universal Design, 1997).

There are seven principles that aim to achieve universally designed product ((NC State University, The Center for Universal Design, 1997) :

- *Equitable Use*: The design should be useful and marketable to people with diverse abilities.

- *Flexibility in Use*: The design should accommodate a wide range of individual preferences and abilities.

- *Simple and Intuitive*: Use of the design should be easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.

- *Perceptible Information*: The design should convey necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

- *Tolerance for Error*: The design should minimize hazards and the adverse consequences of accidental or unintended actions.

- *Low Physical Effort*: The design should be used efficiently and comfortably and with a minimum of fatigue.

- *Size and Space for Approach and Use*: Appropriate size and space should be provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

Inclusive design shares the similar considerations but inclusive design differs from universal design with the strategies for achieving those principles (RICA, 2001).

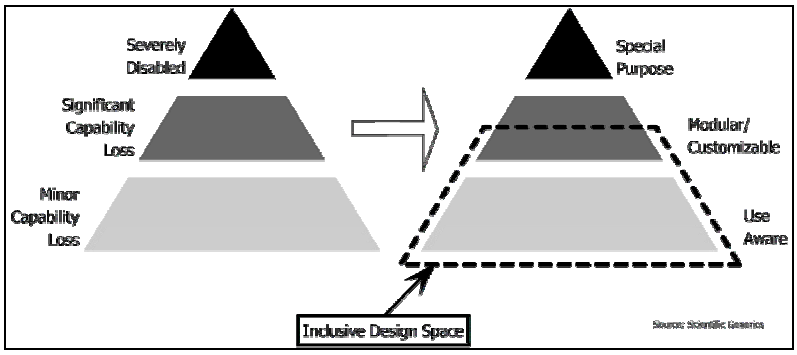

Figure 1-2: Inclusive Design Space
(Figure from RICA, 2001)

In figure 1.2 which was produced by Scientific Generics (cited in RICA, 2001), the section marked as inclusive design space shows the range of disabled population that inclusive design (or universal design) deals with. According to the figure, the "as many people as possible" approach of inclusive design covers a range of people from minor capability loss to significant capability loss. As indicated in the diagram, users with significant capability loss can use products through customizing. Inclusive design aims to diminish the modularity and customizing of products, services and environments when possible and to ensure all products are usable by a broad audience.

Design for all is another term which has same goals. This approach aims a design that involves users with or without disability (ITTATC, 2006).

Barrier free design and accessible design are similar concepts which refer to universal design. However, their origins are different. Both concepts also deal with architectural and environmental designs as well as product design. Moreover, barrier free design corresponds to the barriers in environment. In recent days, accessible design might be used to refer to access to information and technology (ITTATC, 2006).

Exclusive Design

This term refers to the specialized design exclusively for the disabled (NC State University, The Center for Universal Design, 1997). Contrary to inclusive design, exclusive design separates the population as disabled and enabled. It offers different products, services and environments for each ability group.

Transgenerational Design

The term is set forth by Prof. James Pirkl and colleagues. Similar to universal design, transgenerational design claims that all products, services and environments should meet

the needs of users from a wide range of ages with different abilities. Its goal is to make usable products, accessible services and environments for elderly as well as rest of the population (Freudental, 1999).

Assistive Technology

Assistive technology is special design for a particular disability. Assistive technology, as its name implies, serves devices for solution or assistance on a particular subject. Color reading devices for the blind or wheelchair for the paralyzed are some examples of adaptive technology. An assistive technology is preferred when there is no possibility of inclusion into the population. Namely, assistive technology corresponds to the top of the pyramid: Special treatment for severely disability.

Adaptable Design

The adaptable design generally refers to housing or features in housing intended for use by people with disabilities and others. Adaptable design means readily adjusted (NC State University, The Center for Universal Design, 2006). Adaptable design offers housing modifications such as wide doors, no steps for the disabled.

CHAPTER II

USER-PRODUCT INTERACTION

2.1. INTERFACE

When interaction with a product is mentioned, this, in fact, means interaction with the interface of that machine. In terms of ergonomics, the interface can be defined as the media where the user and machine communicate with each other. The interface is a plane in which two different mechanisms with completely distinct working principles meet. Undoubtedly, the machine and the human have different systems in terms of operation. While the machine works based on programs and orders with concrete and rigid rules, man can work flexibly, without a need for any schedules or rules. This flexibility comes at a cost; however, while the machines operate fast, men are much slower (Asatekin, 1997).

2.2. ANALYSIS OF INTERACTION

The interface can be defined as a communication channel between two ends. Consequently, the interaction itself is a kind of communication.

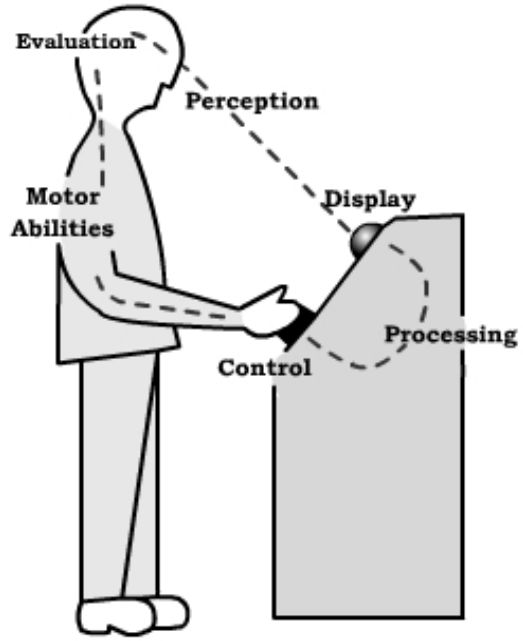

Figure 2-1: Components of the man-machine interaction
(Derived from Asatekin, 1997).

Although different ergonomics sources use different terminology, the basic mechanism (process) of the interaction is the same.

The interaction repeats itself in a loop that begins with the sensation and the perception of the information displayed. It continues with the evaluation of the information. Next, the motor abilities step in and react to the information displayed by the machine through using the control elements. The loop is completed when the machine processes the data it obtained and transfers newly evaluated data to its display units. After this point, a new loop begins, until the task is accomplished.

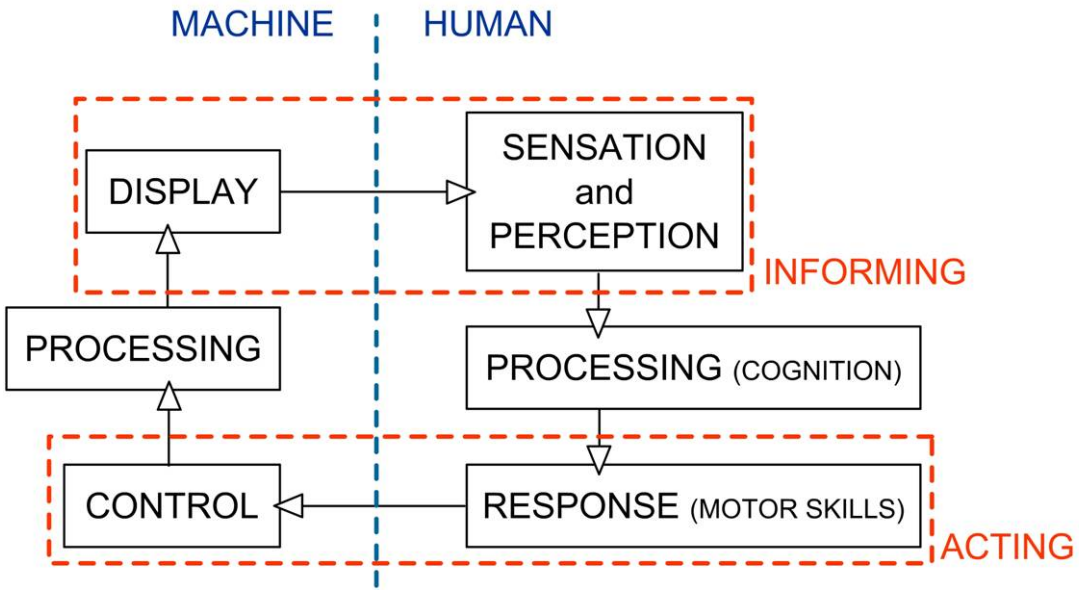

Figure 2-2: Human-machine Interaction
(Derived from Bridger, 1995).

The steps of the interaction loop can be analyzed at the two sides that communicate: The human and the machine.

At the human side, communication has three steps in general: The sensory stage and the processing stage and the stage of response similarly, at the machine side also has three stages: Display, control and processing.

If we view the interaction in terms of the flow of data, the whole interaction can be divided into two processes: The process of informing and the process of acting.

2.2.1. From Sensation to Perception

The initial step in interaction is to be informed. This can be achieved in different ways, according to the user's goal. The user may be informed with the purpose of receiving a

warning, be guided to accomplish a task or be given data for further steps (Kantowitz and Sorkin, 1983).

At the human side, the factor that acts while gathering data is sensation. Perception follows sensation in further stages.

2.2.1.1. Sensation

For humans, sensation is the first stage in perceiving and understanding the outer world. Sensation is a consequence of biological and neurological events. Perception starts with the impingement of a physical stimulus upon a sensory receptacle of a sensory organ and it continues with mental processes that evaluate the data received from the environment. These mental processes are also called respectively perception and cognition (Bridger, 1995).

There are several classifications of the senses according to the frame of reference or purpose. In traditional classification, senses are grouped with the sensory organs they are related to (Kroemer *et al.,* 1994).

Table 2-1: Different Classifications Of Senses
(Derived from Asatekin,1997)

Traditional	Visual	
	Auditory	
	Cutaneous	
	Olfactory	
	Gustatory	
Anatomical/ Physiological	Somatic Senses	Touch, pressure, temperature, pain, proprioception
	Visceral Senses	Pain, pressure
	Special Senses	Smell, taste, sight, sound, balance
According to Types Of Stimuli	Mechanical Stimuli	Touch, sound, pressure, pain, proprioception, balance
	Electromagnetic Stimuli	Sight, temperature
	Chemical Stimuli	Smell, taste

Recent studies include, three more senses in addition to the traditional grouping: The kinesthetic, vestibular and organic senses (Asatekin, 1997).

Visual Sense

The eye is where the visual sensation occurs. It is a mechanism that transmits the light rays reflected from objects to the light-sensitive receptors (Figure 2-3).

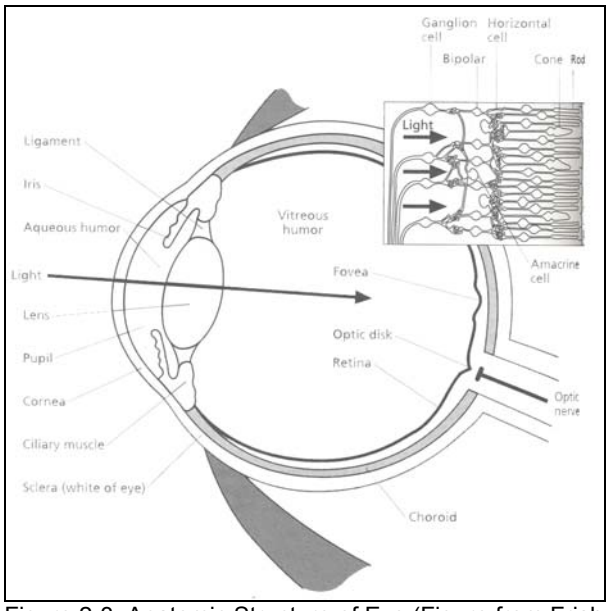

Figure 2-3: Anatomic Structure of Eye (Figure from Frishman, 2005, p:54)

The first contact with the light rays reflected from an object occurs at the cornea. The cornea is a transparent and slightly chambered part of the eye. After passing through the cornea and the clear fluid between the cornea and the lens, the light rays arrive at the pupil, the center of the iris. Through the circular and the radial muscles of the iris, the pupil's circular opening adjusts its radius according to the amount of light received. Namely, the pupil adjusts the level of light entering the eye by changing its size. Light rays are refracted by the lens behind the pupil and are channeled through the vitreous humor that fills the eyeball and fall onto the retina. The retina is where the first step of imaging takes place (Sanders and McCormick, 1993). There are two types of photoreceptors found in the retina, rods and cones, determining the function of the eye.

Cones are used for day vision. Cones respond to high intensities of light. Moreover, their response to light is faster than rods. They can perceive rapid alterations in stimuli quickly. However, they have less pigment than rods, so they need more light to detect images. In addition, cones have higher visual acuity than rods. Loss of cones causes legal blindness.

Rods, on the contrary, function at low levels of illumination. They have more pigment than cones. Consequently, they are very sensitive to light. On the other hand, their response to light is slower and they have respectively low vision acuity. Loss of rods causes night blindness.

Rods and cones are not distributed evenly over the retina. While cones are concentrated in the fovea, rods are concentrated on the periphery of the retina. Therefore to see an object

with high acuity, we must look at that object directly so that light coming from the object is focused on the fovea and we can see objects in our peripheral vision as rough shapes.

The light absorbed by cones and rods initiate a chemical reaction at these photoreceptors which in turn, initiates a neurological impulse. This impulse is transmitted to the brain via the optic nerve. By processing this impulse, a raw image is formed at the brain. Accordingly, the sensation stage is completed and perception begins.

Visual Capabilities

There are a number of functions that the eyes are capable of:

Visual Accommodation: Visual accommodation is the ability to focus the lens so that the light passing through it falls on the retina. Focusing the light on the retina allows seeing the details of an object at a particular distance. There are limits to this ability - there are maximum and minimum distances that eyes can see (Kroemer, *et al.,* 1994).

The visual accommodation capacity of some individuals may not be sufficient enough to see distances too far or too close. These disorders are called nearsightedness and farsightedness respectively and they originate from the failure of focusing the light rays on the retina. In nearsightedness, distant objects can not be seen clearly because the lens focuses the light rays on a spot that is in front of the retina. On the contrary, in farsightedness, objects close to the eyes can not be seen clearly since the lens focuses the light on a spot that is behind the retina.

Visual Acuity: Visual acuity refers to the capability of discriminating the details of objects that are seen. Depending on the type and the detail of the perception of the object, there are some types of acuity:

Minimum separable acuity is the smallest feature or the smallest space between two parts that the eye can detect. The smallest target distinguishable from its background is minimum perceptible acuity (Sanders and McCormick, 1993). Dynamic visual acuity is the ability to make visual discriminations when observer and/or the target is moving.

Contrast Sensitivity: Contrast sensitivity, which may be mentioned under visual acuity, is the ability to see black and white details of an object. In other words, contrast sensitivity is the ability to differentiate the light level of details.

Visual acuity is the most important ability that affects the function of the eye. Along with accommodation, the loss of visual acuity is the reason of several visual impairments. There

are several variables that affect both visual acuity and contrast sensitivity. In addition, visual acuity might also be affected by physical conditions - visual acuity depends strongly on environmental variables, such as illumination, the contrast between the target and the background or the motion of the target and/or the observer. Accordingly, a normal eye might not function properly under insufficient circumstances such as a high level of darkness, an extreme luminance level or when facing very shiny surfaces. Consequently these external conditions may cause categorizing a normal eye as impaired or disabled.

Adaptation: Adaptation is the sensitivity of the eye to light. There are two types of adaptation: Adaptation to dark and adaptation to light. While the eye can adapt to light quickly, adaptation to dark takes a bit more time.

Color discrimination: Color discrimination is the response differences of cones to different wavelengths. These differences occur because there are three distinct types of cones, with each type being sensitive to a range of wavelengths. These wavelengths correspond to the colors, red, blue and green. Color discrimination disorders for some of the colors cause color blindness.

Convergence: Convergence is the cooperation between the two eyes. Both eyes can focus on a single target together because of convergence.

Stereopsis: Stereopsis is the ability of depth perception. Stereopsis results from the differences in the images perceived by the left and the right eyes.

Auditory Sense

The ear, which is a sensory organ sensitive to sound vibrations, can be examined in three anatomical sections: the outer ear, the middle ear and the inner ear.

Outer Ear: The outer ear consists of the external part of the ear that is called pinna and the auditory canal (Kandel, 2000). The function of the external part of the ear is to collect the sound energy from the environment and transmitting it to middle ear through the auditory canal.

Middle Ear: Sound waves coming through the auditory canal hit the tympanum which is another name for the eardrum. Sound energy coming from eardrum is transmitted to the inner ear by the ossicles behind the eardrum, which are called malleus, incus and stapes. These delicate bones transform low pressure sound waves to high pressure sound waves because inner ear contains liquid, rather than air.

Inner Ear: The inner ear is composed of cochlea. As mentioned earlier, the inner ear is filled with liquid and stapes create vibration in this liquid. The vibrations reach the basilar membrane. The basilar membrane transmits these vibrations to the corti which is an organ that contains hair cells and nerve endings. As soon as vibrations reach corti, they are picked up by these nerves which are sensitive to slight changes in pressure and they are transmitted to the brain via the auditory nerve (Proctor and Proctor, 1987).

Cutaneous Sense

The cutaneous sense corresponds to sensation about the skin. There are different classifications for the cutaneous sense. One classification is based on the type of stimuli that triggers the sensation. The types of stimuli, according to this classification, are thermal, mechanical, chemical and anatomical (Geldard, 1972; cited in Sanders and McCormick, 1993). However, generally the sensation of touch is examined under three titles: The pressure sense which refers to touch, the sense of pain which is called as nociception and the temperature sense which is thermoception.

There are different types of receptors in the skin, including free nerve endings and encapsulated nerve endings. The reason why there is no consistence between the typology of cutaneous sense is that there is no precise association between a particular receptor and a particular type of sensation (Fogel, 1967).

In addition, touch can be divided into two categories: Passive and active touch. While passive touch refers to an external pressure on the skin, active touch refers to touching something by the conscious will of the individual (Gibson, 1966; cited in Sanders *et al.,* 1993).

Olfactory Sense

The olfactory sense corresponds to the sense of smell. The odorous molecules in air dissolve in the mucus present in the nasal cavity. The dendrites of the olfactory nerves are located on the upper part of the nasal cavity and they detect the molecules dissolved in mucus. The olfactory nerves transmit the information directly to the olfactory bulb, the section of the brain related to the sense of smell (Fogel, 1967).

Gustatory Sense

The gustatory sense, or the sense of taste, is the sensory system that uses taste buds to detect the taste of a food being eaten. Most of the taste buds are located on the surface of the tongue. The five basic types of taste buds humans have can detect the salty, sour, bitter,

sweet and savory tastes. The information obtained from the taste buds are carried to the brain via three different cranial nerves, depending on the location of the taste bud on the tongue (Fogel, 1967).

Kinesthetic Sense

The kinesthetic sense is the sense of the position of the parts of the body, relative to the other neighboring parts of the body (Fogel, 1967). It is the sense that allows someone to walk in complete darkness, or to drive a car without looking at the steering wheel or the foot pedals. Unlike the external senses, the kinesthetic sense is internal and is a key component in muscle memory and hand-eye coordination. The kinesthetic sense is trainable; it is possible to learn complex activities like juggling by improving kinesthetic perception of the body.

2.2.1.2. Perception

The second step of the informing stage in communication with a product is perception. Basically, perception is a stage-wise and hierarchical process of evaluating, interpreting and organizing sensory data. Perception starts with identification of the stimulus from sensual organ and continues with higher mental processes including cognition (Bridger, 1995).

Sensing of environment transfers not necessarily what that data means. There is a need to interpret the data using previous experiences or skills and knowledge which were learnt or trained. In other words, what we sense is actually a coded version of the external data.

As Bridger (1995) mentions, the perceptual process is in fact the initial step in decoding the environmental stimuli. Bridger says the concept of coding in computers resembles information processing in humans. In the perceptual stage, the raw data obtained by senses and is transmitted to the higher centers of the brain, where it is processed and coded into understandable parts.

The study of perception does not contain consistent and widely-accepted theories and classifications since the research in the field depends on psychological and behavioral experiments. Therefore, there are several approaches to perception. In this study, perception will be examined in terms of ergonomics under the three main titles: Visual perception, auditory perception, and cutaneous perception.

Visual Perception

Visual perception starts with sensing the first pattern of illumination on the retina. The process continues in the optic nerve, the lateral geniculate nucleus and the visual cortex of the brain.

In visual perception, when interpreting visual data, the data taken into consideration is not only the pattern of illumination that had occurred at the retina; data learnt from past experiences and other senses also play a role (Gregory, 1997).

In visual perception phenomena, as in the concept of perception generally, there are many variables and external factors that affect the revelation of visual data coming from senses. Hence, several theoretical approaches to the visual perception phenomena have emerged due to its complicated and controversial nature.

"Unconscious inference" by Helmholtz

Helmholtz (1866) claims the perception of vision is inferring the reasonable interpretations from incomplete data. The aim of vision is to get as much data as possible to apprehend the environment. Since sensory signals are not sufficient to perceive the outer world truly and entirely, further synthesis of the visual data with the data from our experiences and other senses is required (Gregory, 1997).

Bayesian Theory

If the visual system benefits from the empirical information to generate perception of real world and objects, to understand the vision statistically, is to understand how the relationship between retinal images and their physical sources takes place. In this context, Bayes adopted his "decision theory" to understand visual perception.

In vision perception, Bayesian Theorem is used as a means to rationalize the percepts provided by a visual stimulus. The purpose of the Bayesian theorem is to determine physical sources for a given retinal image and the possibilities of these to happen. As a result, the possibility of real image of the world perceived is predicted.

Empirical ranking theory is an alternative to the Bayesian decision theory in the issue of perception. In decision theory, a percept provided by a particular stimulus is evaluated statistically according to the values determined in qualities and conditions of the physical world. In the empirical ranking theory, contrary to decision theory, the percept is compared with the other percepts which have occurred in the past experiences of the observer. In other

words, the vision perceived is determined by the past experiences with the perception of similar scenes (Geisler and Kersten, 2002).

Ecological Approach

Gibson, who is a psychologist and a pioneer of the ecological approach to vision, has a point of view radically different from both Helmholtz and the Bayesian theory. He discusses that there is adequate quantity and type of data to perceive the physical world and interpret explicit information about it.

According to Gregory (1998), Gibson's theory of vision has a kind of realism in defending the point that perception comes from directly the external world rather than inferences such as memories from past experiences. He called his conception as "stimulus ecology", referring to the stimuli that surround the individual.

Gestalt Rules

Gestalt rules are studied by a group of German psychologists in 1920s. The German term of "gestalt" means wholeness. Contrary to previous theories, Gestalt theorists claim that perception of objects and patterns do not taken place in brain. Instead, when the eye sees an image, it looks for some patterns, relations. Correspondingly, the eye interprets the image. This skill of interpretation patterns is not inherited from the parents; it improves with the development stage of individual.

In this respect, Gestalt rules discover how the brain perceives. This rule is about *detection of symmetry, detection of patterns and perception of figure and ground* (Baxter, 1995). Human eye has an excellent ability in *detection of symmetry*. Even if the object seems distorted because of the point of view, the eye can perceive the symmetry. Based on the symmetry rule, there is a *geometric rule*. Geometric rule is the detection of regular patterns rather than irregular or complex geometric patterns.

The second type of rule is about *detection of patterns*. These rules are further divided in three categories as *proximity, similarity and continuity*. *Proximity rule* refers to the detection of objects that are placed close to each other. The proximity rule says that objects close to each other are perceived as a pattern. According to *the similarity rule*, similar objects are perceived as a whole. The *continuity rule* states that objects that seem to be a part of or the continuation of another object, are perceived as a unity.

The third subject of the Gestalt rules is about *discrimination of figure and ground*. When the eye looks at a figure and its background, there are some rules on how the eye determines

which objects as the figure and which objects as the background. These rules are based also on other Gestalt rules; symmetry, relative size, surroundings and orientation. (Baxter, 1995) The eye tends to perceive an object which is symmetric, relatively smaller, surrounded and oriented as vertical or horizontal as a figure.

Auditory Perception

Perception of sound can be analyzed according to concepts about the auditory system (Sanders and McCormick, 1993):

Perception of loudness: Loudness is the perception of the physical magnitude of the sound. In other words, intensity of the sound is perceived as loudness. There is no direct proposition between the perceived loudness and the actual intensity of the sound. If the ear continually experiences high levels of sound, much higher levels of sound might not be experienced as loud.

Perception of Pitch: Pitch can be described as repeating patterns in a sound. There are two kinds of pitch perception: Perception of pure tones and perception of complex tones. Pure tones are the basic type of tone. Their repetition rate equals to the frequency of the tone. Complex tones are repeating patterns which contain complex harmonic tones.

Perception of Spatial Hearing: Perception of spatial hearing is the perception of the difference between sounds that reach each ear. The human ear can determine the relative location of a sound source using the differences in the sound as it arrives at each ear. There are two types of differences: *Time differences are* caused by sound arriving at one ear before another. *Level differences are* caused by the intensity of sound arriving at one ear being higher than the other.

Perceptual Organization of Sounds: Perceptual organization of sounds is the ability to discriminate different sounds and their sources in an environment. The human ear is also capable of eliminating all sounds except one that is desired to hear.

Cutaneous Perception

Although cutaneous sense seems as a supportive sense to other senses, especially the visual system, cutaneous sense is the most important sense when substituting for visual sense in blindness. A sighted person can perceive the properties of the object such as its material, stiffness and weight by his/her visual sensation. On the other hand, a non-sighted person can discriminate an object via only one channel of sensation; cutaneous.

In cutaneous perception, the action of touching can be active and passive. Active touch or haptic perception is the perceptual data gathered via direct manipulation while touching an object. Passive touch is generated by stimuli from external source to the steady observer (Gibson, 1966; cited in Proctor and Proctor, 1987).

Weisenberger (2005) examines cutaneous perception under three sections according to the current literature:

Tactile pattern perception refers to the perception of embossed lines, symbols and letters. According to Loomis's study, (1981; cited in Weisenberger, 2005) the perception of a raised letter is so accurate that it gives a perception feel similar to a letter seen blurry. However, there might be confusions in perception of letters which are similar in form.

Braille letters are example of successful pattern perception. Dots in Braille letters are placed in a simple way with identical spaces and they do not cause trouble in depth perception as embossed letters do.

Texture perception refers to the perception of surface texture. When perceiving the texture, repeating patterns are felt. These repeating patterns may be of random or uniform textures. In texture perception, the roughness of the surface is perceived first (Hollins, *et al.,* 1993; cited in Weisenberger, 2005).

According to Lederman's study, in the perception of texture, the movement of the finger over the surface does not effect the perception of roughness; the finger can be stationary as well. In other words, perceived roughness of surface is the same in any case. However, if the finger increases pressure, the perceived roughness level of the surface increases (1987; cited in Weisenberger, 2005).

Object identification in fact, is the purpose of the haptic touch. Lenderman and Klatzky (1987; cited in Weisenberger, 2005) introduced a term called Exploratory Procedures (EP). EP consists of hand movements which aim to explore and obtain data about an object. There are three types of EP. First type of EP is hand movements pressing the object to provide information about the hardness of the object. Second type of EP is moving a hand over the surface to obtain texture data. Third type of EP is moving the hand on the edges of the object, intending to get accurate shape information.

Finally, the time interval in which the identification of object takes place depends highly on the complexity of the object (Ballesteros, *et al*., 1997; cited in Weisenberger, 2005).

2.2.2. Processing Stage

Process of information, which starts with cognition, is the initial step of decision making. In a given time period, of the many stimuli impinged upon the senses, only a few pass the threshold and generate a perception. The perception may or may not continue with further consequences depending on variables in the brain, such as the recognition of the stimulus or making a decision and performing a task.

2.2.3. Stage of Response: Motor Skills

During communication with a machine, after perception of the message from the interface given through display elements, the next step is the recognition and identification of the message. For example, the perception of a green button is compared with the past experiences and is recognized as the green execution button which would to start a task. After the higher mental processes, a decision is made: to press the button in order to begin the task. Until this point, all the events take place in the mental level. In the action stage, while pressing the button, the main role belongs to the motor skills.

Motor skills refer to the ability of conscious movement of skeletal muscles. They depend on the proper functioning of the skeleton, skeletal muscles, the nervous system and metabolic processes (Asatekin, 1997).

There are two types of motor skills, *gross* and *fine*. *Gross motor skills* refer to the ability to move the body itself or to control parts of the body to allow movements such as walking or sitting down. *Fine motor skills* refer to the relative precise control of muscles and sometimes entail using effective eye-hand coordination (Kroemer, et. al., 1994).

Types of Movements: In man-machine interaction, in terms of ergonomics, there are some types of movements the human performs during the physical interaction such as flexion, extension, adduction, abduction, medial rotation and pronation supination (Kroemer, et. al., 1994).

2.3. COMPONENTS OF THE PRODUCT INTERFACE: DISPLAY AND CONTROL ELEMENTS

As mentioned in the beginning of this chapter, interaction can be defined as a type of communication. In the mechanism of communication, there is a data sender and a data receiver. In the case of man-machine communication, the human and the machine are data sender and the data receiver. However, since communication consists of data exchange-loops, both the human and the machine play the roles of the sender and the receiver in an

exchange loop. In this information exchange loop, displays are the devices conveying information that can not be easily sensed, from the machine side to the human side.

Similarly controls also play a role in the communication channel between the machine and the human. Control elements are devices used by the human to transmit the data to the machine. Moreover, control elements, at the same time, may function as a display in order to provide necessary feedback to the human about the result of the action.

As communication modes are based on the human senses, display and control elements can be differentiated according how they communicate with the receiver. Displays and control elements may target visual, auditory, tactile senses.

In this part of the study, characteristics and functions of displays and controls will be examined briefly. Displays and control elements will categorized so that a basis, on which the observation results in the next chapters can be discussed, will be formed.

2.3.1. Display Elements

Displays convey data from the machine to the human. According to the type and the nature of the data conveyed, displays come in different forms. In general, the purpose of a display determines which type of display is used (Cushman and Rosenberg, 1991):

To display Qualitative Information: These displays convey qualitative information, such as to display the amount of fuel left in the gas tank in automobiles. (e.g. ¼ of the tank is full or 4/4 of the tank is full)

To display Quantitative Information: These displays are used when the information conveyed will be used in a task that requires precise calculations or exact numbers.

To indicate Status: These displays give information about the status of the machine, such as “out of print” light on printer.

To convey Warnings: These displays are used when a problem or emergency occurs.

Apart from these, these are two more uses of displays which are categorized as *static*:

To identify a function: This use consists of labels for controls.
To instruct: This use aims to help or orient the user during or before performing a task.

2.3.1.1. Visual Displays

Visual displays as their name implies, target the visual sense of humans. Visual displays are the most frequently used type of displays. The main constraint of visual displays is their considerable reliance upon the visual capabilities of the user. Hence, when a visual display is not supported with other types of display, problems emerge for users with visual impairments.

In spite of the variety in the typology of visual displays, in general they can be studied under two main titles: dynamic and static. *Dynamic displays* are the ones that change (or the value that they indicate changes) in time. *Static displays* are those that show fixed information that does not change in time, such as labels and pictograms. Apart from these, there is one more type that can be either dynamic or static: d*igital displays*.

Dynamic Analog Displays

Dynamic analog displays can be divided into two main categories according to the type of information displayed. Data changing in time can be represented in exact numbers or it can be shown as a range or a ratio between two extreme values such as full and empty (Figure 2.5).

Quantitative analog displays have some mechanical parts such as pointer and scale. The typology of these displays is determined according to the movement of these parts.

In displays of the type *fixed scale and moving pointer,* while the scale is fixed, the pointer is moving. They can be in different shapes, such circular, and semi circular or horizontal (Figure 2.4).

In displays of the type *moving scale and fixed pointer,* while the scale is moving, the pointer is fixed. Similar to the previous display type, this kind of displays can have various forms such as circular, open-window, vertical and horizontal (Figure 2.4).

Figure 2-4: Moving Pointer, Fixed Scale Displays

In analog displays mechanic counters can also be present. Such displays are a differentiated design of circular moving scale and fixed pointer.

Qualitative Displays

Qualitative displays are used to represent a value which is categorized or ranged. The displays that point certain situations such as warning, an emergency situation or offer guidance are qualitative displays. There are several types of qualitative displays in terms of the type of information that is displayed.

Qualitative Zoning of Quantitative Dials

This kind if of display is used to convey numeric values that are categorized or divided into reasonable zones. If there is no need to convey exact values, data is represented by pre-coded qualitative values, symbols or numbers.

Figure 2-5: Examples to Quantitative Displays

For instance, the temperature might be represented in three zones as hot, warm and cold. In fact, there are pre-determined temperature ranges for hot, warm and cold. Qualitative displays are useful in observing the trends or the rate of change of the values. Accordingly; they are preferred tasks in which keeping the status or condition of a value within the particular range is important (Sanders and McCormick, 1993). The design of the qualitative displays can be in the form of a scale and pointer (Figure 2.5). Qualitative displays can also be embedded within quantitative displays.

Qualitative symbology is another design form for transmitting ranged values. Qualitative symbology shares the same reasoning and many features with zoning. It differs from zoning in terms of design. Qualitative symbology uses the symbolic representation to display the situation or the categorized numeric value.

Check Reading

Check reading is used to check if a value is in the normal range or not. Similar to previous types of displays a moving pointer and fixed scale combination is used in the design of this kind of display. In this type of display, the value accepted as normal is represented with particular position of the pointer. This position is usually aligned at the 12 o'clock or 9 o'clock. Other positions are marked as outside the normal range.

Status and Warning Information Lights

If the information that is conveyed is about a status or a warning, indicator lights are used. Indicator lights might be flashing or steady-state or they may have two stages that are represented by different colors. The lights can also indicate a two-option situation by being on or off. There are various uses for status and warning lights (Sanders and McCormick, 1993):

- *Power-on lights indicate* whether the electric power is present in the device or not (Figure 2.6).
- *Function active lights* point out which function of machine is active at present.
- *Operating mode lights* inform about which mode of operation is active in the machine.
- *Localizer lights* display the status of more than one function (Figure 2.7).
- *Hazard lights* warn about a potentially dangerous situation.
- *Malfunction lights* warn that an error or malfunction has occurred in the equipment.

Figure 2-6: Power On Lights

Figure 2-7 Localizer Lights

Pictorial (Representational) Displays

Representational displays illustrate the real situation of operating. These displays can either be dynamic or static. Moreover, pictorial displays can be observed often in digital displays (Sanders and McCormick, 1993).

Static Displays

Static displays represent steady information in order to guide the user, provide help or advice or give a command. Many applications of static displays, such as labels, maps, charts, instructions, pictorials in manuals can be met in daily life (Kroemer, *et al*., 1994).

The factors that affect the functionality of static displays as well as dynamic displays most are visibility and readability of the alphanumeric characters and graphics. In the product interface, static displays can be used mostly in the form of labels and instructions. Furthermore, signs, pictorial signs, maps and charts are the other types of static displays which might be observed.

- *Labels*: The aim of labels is to indicate the function of the control or the value the display shows. Labels can involve words or pictorial symbols (Figure 2.11).

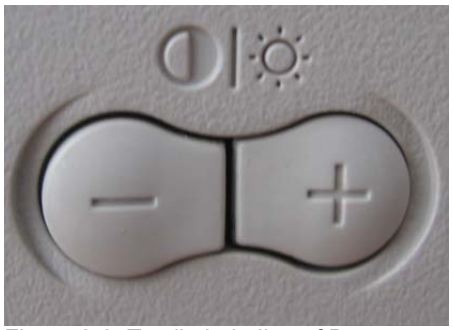
Figure 2-8: Tactile Labeling of Buttons

Figure 2-9 Labeling with Letters and Symbols

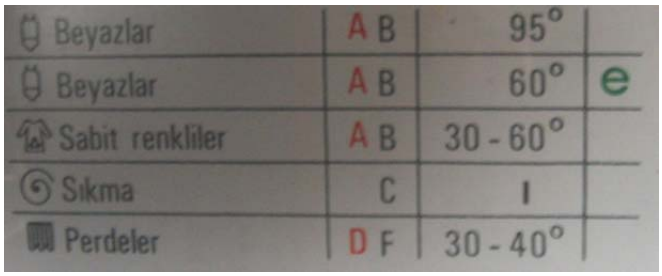

Figure 2-10 Instructions for a Washing Machine

Figure 2-11 Pictorial Labels

- *Instructions*: Instructional materials assist the user in operating the product. They can be written in text or might be in the form of pictorial materials (Figure 2.10).

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2.3.1.2. Auditory Displays

Different necessities and different environmental conditions entail different modes of displays. For instance, a visual (color coded) signal light is useful in a noisy working environment. On the other hand, an auditory display might be more suitable for a working environment where the operator is mobile.

Auditory displays are used mostly as warning signals today. Apart from sound signals, speech might also be used as an auditory display. Furthermore, an auditory display can be used simultaneously with a visual display to draw more attention. There are several aspects of auditory signals regarding human functions (Sanders and McCormick, 1993):

Detection is the ability to perceive the auditory signals.

Relative discrimination refers to the discrimination of one signal from the other.

Absolute identification is the ability to discern an auditory sound, for example, to recognize the sound of a bell, a chime or the sound of a particular animal.

Localization refers to the identifying source of the signal and where the signal comes from.

In general, an auditory display is limited to much lower information rates when compared to the visual displays. In the situations where the visual system is not possible or is precluded by the environment or other tasks, the medium to high information levels provided by auditory displays are used (Kantowitz and Sorkin, 1983).

Auditory signals may be in three different types: *Simple tones*, *complex tones* such as bells, horns, sirens or chimes and *spoken messages*. (Cushman and Rosenberg, 1991)

Tonal Signals

Tonal Signals have relatively low-medium information rate. They can be used for displaying the status, giving a warning or display qualitative information. Tonal signals are preferred over spoken messages when (Cushman and Rosenberg, 1991):

An immediate response from the operator is needed,

The operator must be warned that a spoken message is about to follow,

The noise in the environment hinders spoken messages,

Spoken messages might disturb other operators.

Due to their specific characteristics, complex tonal signals are also suitable for auditory warnings. In addition, different compositions of complex signals may convey different messages.

Spoken Messages

Spoken messages have a higher information rate than tonal signals. They are preferred in situations where (Cushman and Rosenberg, 1991):

A high degree of message flexibility is required,

Tonal signals may not be enough to convey the message properly in adequate detail,

The operator has no training.

There are three types of spoken messages according to the way how the speech is generated: *Pre-recorded*, *digitized speech* and *synthesized speech*.

Pre-recorded messages

Pre-recorded messages are produced via recording the whole message by human vocal. This kind of display has excellent quality of speech, but it costs considerably more than other speech generating methods.

Digitized Speech

For digitized speech, a set of words are recorded by human vocal and then, according to the content of the message, these recorded words are composed into a sentence or phase. This type of spoken message is relatively more effective in terms of cost and quality.

Synthesized Speech

Synthesized speech is the most technologic one. No verbal human input is required. The words and the phrases are generated by computer signals. The advantage of synthesized speech is that it has unlimited word capacity. Almost all words and messages can be generated simultaneously during the operation (Cushman and Rosenberg, 1991).

2.3.1.3. Tactile Displays

Although we use our cutaneous sense often in daily life, in product interfaces there are very few applications that entails to use tactile sense for receiving data.

Tactile controls may be used to diminish the possibility of error via enhancing the distinguishability of the control. Moreover, they are used for overcoming difficulties in a disability situation of hearing or sight in operator that may be caused by impairment or environmental conditions such as noisy or dark places. To conclude, tactile displays are generally used as subtitles for seeing and hearing (Kantowitz and Sorkin, 1983).

Substitutes for Hearing

Tactile displays which are used as replacements for or to support hearing sense are frequently in the form of mechanical vibration of electric impulses. There are some studies about implementation of tactile displays regarding auditory displays (Sanders and McCormick, 1993).

Reception of tonal signals is the use of electro-mechanical vibrations to transmit the tonal audio signals.

Reception of spoken messages is an experimental study which is based on the method transmitting voice via electro-mechanical stimulus through skin.

Localization of sound is another experimental study as well. It is based on the principle of transmitting the sound coming to the microphones at each ear, to index fingers as vibration. Similar to localization of sound, in this experimental study, the location of the sound source is identified according to the comparison of the vibrations that each index finger feels.

Substitutes for Sight

The purpose of tactile displays and controls may be enhancing the usability of the interface or enabling the use of the product by an operator with visual impairment. Tactile displays and controls range from very simple to technologic ones.

For identification of controls: Tactile interface elements are used mostly to identify the control components. The controls distinguishable by touch may have unique shapes or texture.

Reading Printed Material

This application of tactile displays is used mostly in printed materials for the blind such as Braille printing. This application of tactile displays has no prevalent usage in product design. In some interface designs, raised dots (although not as in Braille alphabet), stripes or bars are used to display some of the symbols or to form reference point for adjustments (Sanders and McCormick, 1993).

2.3.2. Control Elements

Controls are the activators of the product (Kroemer, *et al*., 1994). They transmit the order from the operator to the processor of the machine.

Control devices may be made from many different materials. They may also have different working principles and technologies such as mechanical, electronic, electromechanical, optical, magnetic, and piezoelectric. In ergonomics and design, requirements or characteristics of the task determine the design of the control elements (Kantowitz and Sorkin, 1983).

Controls are classified according to their function. Before examining control types, some common types of tasks will be mentioned briefly. Cushman and Rosenberg (1991) divide tasks into six categories:

Single discrete tasks involve tasks such as turning on and turning off, or selecting one of the various modes.

Selection of a quantitative value refers to tasks which require the input of a quantitative value, such as setting a thermostat to a specific temperature.

Adjusting an output involves tasks in which a value which is a continuum between two positions is adjusted such as adjusting the volume.

Serial tasks refers to the tasks that must be performed by following specific orders, such as setting up a timer for recording in a VCR

Data entry is a task in which a series of data is input in a machine, such as using a calculator or dialing a number on the phone.

Continuous motor tasks involve tasks that must be continued during the whole operation, such as steering an automobile.

2.3.2.1. Types of Control Elements

The purpose of the control element defines the physical characteristics and the design of the appliance. To illustrate, if there is a need for an on-off function, i.e. a single discrete task, a button which can be positioned at two points can be preferred.

Regarding this task typology, controls can be divided into two broad groups as discrete and continuous (Pheasant, 1986). Controls for discrete tasks are used for selecting one of the limited numbers of modes of operations such as power on-off or low-medium-high. Controls for continuous tasks involve adjusting a value on a continuum such as adjusting a volume control ranged between 1 to 100, the gas pedal for controlling speed or turning a valve between fully open or fully closed positions.

Table 2-2: Basic Taxonomy of Controls (Derived from Cushman and Rosenberg, 1991)

DISCRETE TASKS		**CONTINUOUS TASKS**
Two Positions Controls	**Multi-Position**	
Push Buttons Push-Pull Switches 2-Position Slide Switches Foot Operated Push Button Rocker Switch 2-Position Toggle Switch	Toggle Switch Paddle Switch Rotary Selector Detent Thumbwheel Step Keys Keypads Detent Levers T-Shaped Handle	Rotary Knob Sliding Controls Small Crank Continuous Thumbwheel Small Levers Pedal Hand Wheel

Push Buttons

Push buttons are one of the oldest and most common types of control instruments. They are finger operated and function at discrete tasks such as turning a product on or off or changing the operation from one mode to another. Push buttons come in a number of styles and are classified according the their control action (Kantowitz and Sorkin, 1983);

Figure 2-12 Power Push Button

Figure 2-13 Latching Push Buttons

Momentary (push-on, release-off) push button is active as long as it is pressed. When the button is released, it turns off.

Latching (push on/lock, push off) push button becomes active when pushed once. When the button is released while it is on, it does not return to its original position, but remains at a protrusion level lesser than that of the off position. The button remains turned on until it is pushed once more (Figure 2-13).

The *alternate (push-on, push-off) button* is similar to the latching push button, but its position does not change when it is on. First push on the alternate button turns it on and second push turns it off (Figure 2-14).

The major drawback of this type of button is that the on or off position of the button can be discerned visually. Hence, generally, an indicator light integrated into or placed next to the button may be used. The light turns on when the button is activated.

Figure 2-14 Alternate Push Buttons

In some designs, buttons, mostly alternate buttons, are used backlighted with an integral label. These types are called *legend switches*. Legend switches may be used instead of two position buttons if the space on the panel is extremely limited.

Push-Pull Switches

Push-pull switches are used instead of on-off push buttons. In some products, a push-pull switch which can rotate may be used for continuous adjustment (Cushman and Rosenberg, 1991).

Two-Position Slide Switches

Two-position slide switches are used for turning on-off tasks or for mode selection (Figure 2-15). Their main benefit is that the possibility of accidental activation is very low. In addition, if a group of slide switches are arranged in a row, noticing a switch which is at different position than the rest is easier when compared to previous two-position controls.

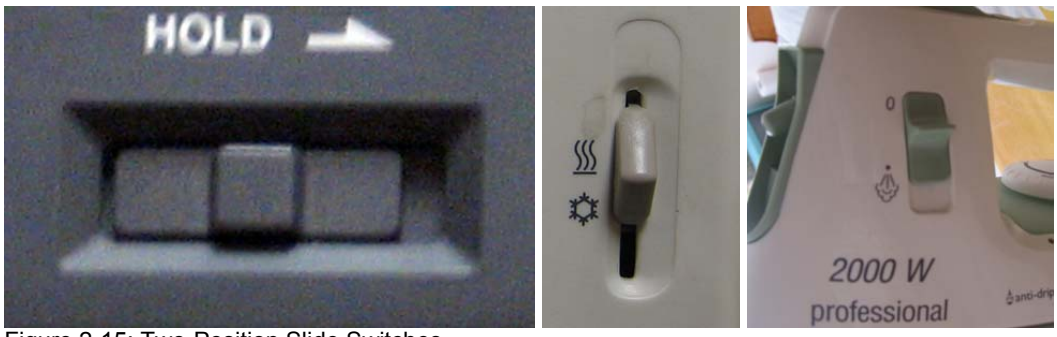

Figure 2-15: Two-Position Slide Switches

Foot Operated Push Button

A foot operated push button may be preferred in two cases: When hands are occupied or the operation needs force (Figure 2-16).


Figure 2-16: Foot Push Button

Toggle Switches

Toggle switches have a wide variety of sizes and shapes (Figure 2-17). Besides serving in two discrete positions, they can function in three dimensions. They are preferred in cases

where space is somewhat limited. When the space constraints are extreme, miniature toggle switches can be used.

Figure 2-17: Two-Position and Four-Position Toggle Switches

Paddle Switches

Paddle Switches are used instead of toggle switches when a larger control surface is desired. Their major drawback is larger space requirement.

Rocker Switches

Rocker Switches are another alternative for toggle switches (Figure 2-18). Since using toggle switch frequently over a long period may cause some injuries in the finger, rocker switches are preferable for frequent and long term usage.

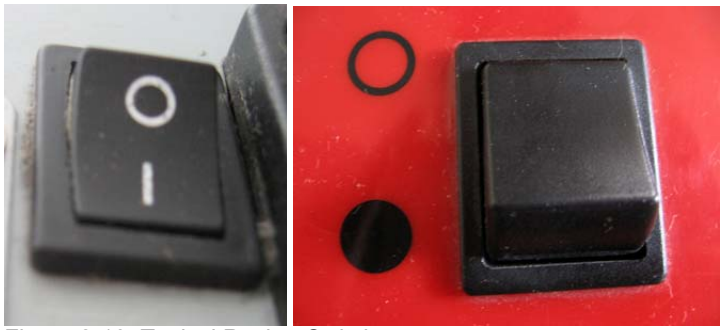

Figure 2-18: Typical Rocker Switches.

Rotary Selectors

A rotary selector is a switch that serves a task requiring 3 to 24 discrete positions (Figure 2-19). A typical rotary selector is a circular knob with a notch or dot to indicate the position of the control. Each discrete position is labeled or marked with a scale marking to provide visual identification about the position of the knob.

Figure 2-19: Left: Three-Position Rotary Selector, Right: Ten-position Rotary Selector.

Step Keys

Channel selectors and volume up-down controls for TV remote controls are typical examples of step keys. Step keys generally used as pairs. Each button in the pair refers to one polar, such as reduction-enlargement, up-down, increase-decrease and next-previous (Figure 2-20). The disadvantage of step keys is time required when moving between steps. For this reason, in some designs, when pressing a key for more than a specified duration, an accelerator is activated and steps are skipped quickly.

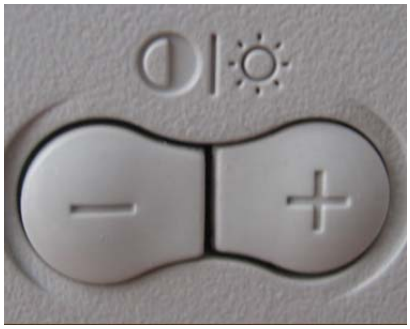
Figure 2-20: Step Keys

Detent Thumbwheel

Detent thumbwheels are used with numeric values. They are not appropriate if precision and speed of the operation is important (Figure 2-21).

Figure 2-21: Detent Thumbwheel

Key Pads

Keypads are small, specialized keyboards and are used as data entry devices (Figure 2-22). Accordingly they are used for the tasks involving quantitative value selection as well as data entry tasks. As the functions of key pads increase with technologic innovations, it can be said that they are going to replace several types of controls.

Figure 2-22: Key Pads

Detent Levers

The gear sticks in automobiles is the typical example of detent levers (Figure 2-23). Detent levers can have more than two positions.

Figure 2-23: Detent Lever

T-Shaped Handle

T-shaped handle operates at two positions. It is preferred for tasks requiring force.

Rotary Knob

Rotary knobs are used for several purposes and are available in several sizes. Their diameter may range from 10 mm to 100 mm. Rotary knobs are chosen for the tasks that require accuracy and continuous adjustment. In fact, there is a relation between the size of the knob and the precision level desired. For comfortable gripping and control, knobs with bigger sizes are more suitable.

Figure 2-24: Left: Rotary Knob, Center: Rotary Knob recessed to ease controlling, Right: Rotary Knob with Pointer.

Rotary knobs may be single-rotation or multi-rotation. If precision is more important, multi-rotation knobs can be used. Apart from this, single-rotation knobs entail a notch or a dot on circumference to identify the position of the control.

Sliding Controls

Sliding controls are observed mostly in the interfaces of audio systems (Figure 2-25). They are identical with rotary knobs in terms of function. Sliding controls can be selected as an alternative to rotary knobs for design or aesthetic purposes. If all other factors are the same, sliding controls are not as precise as rotary knobs.

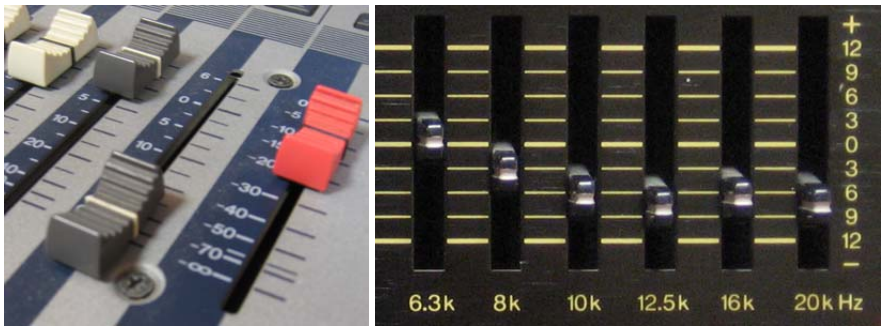

Figure 2-25: Sliding Controls

Small Crank

Unlike multi-rotation rotary knobs, small cranks, usually multi-rotational, are selected when the accuracy and speed of the control is relatively unimportant (Figure 2–26).


Figure 2-26: Small Crank

Continuous Thumbwheels

When the range of adjustment is small and the interface space is very limited, continuous thumbwheels may be preferred (Figure-2–27). To save more space, generally, only about one fourth of the wheel is visible. Volume controls of walkmans are typical examples for this type of control.


Figure 2-27: Continuous Thumbwheels

Small Levers

If a continuous adjustment with a small range and linear control movement is required, small levers may be suitable. A joystick is an example of a small lever.

Pedal

The most common application of pedals can be observed in automobiles (Figure 2–28). Pedals can be appropriate if a large force is needed to operate the control, when hands are occupied or when precise or numerical adjustment is not important for the task.

Figure 2-28: Pedal

Hand Wheel

A hand wheel is a control for two-handed operation. Similar to the pedal, the most typical application of hand wheels are the automobile steering wheels (Figure 2–29). Hand wheels which are used generally in large systems, are preferred when large forces are needed to operate the control.

Figure 2-29: Hand Wheel

2.3.2.2. Identification of Controls

As described in previous sections, there are numerous types of control elements, and these elements have only a few features common to all them. Some of these common features

include shape coding, size coding labels and resistance (Kantowitz and Sorkin, 1983). These features are the factors that provide identification and distinguishability among similar control devices.

Shape coding is used to make similar control devices that activate different tasks distinguishable. For example, push buttons can be coded as round or rectangular. In the case of levers, handles with different shapes and textures can be a method for identification of different controls. Shape coding is an essential factor because it addresses both visual and tactile perception.

Size coding, like shape coding, is another method for stressing the difference between similar control elements. Generally, the size of the control device conveys a message about the importance of the control or the accuracy of the adjustment. As mentioned earlier, the size of a knob is determined according to whether a precise control is needed or not. Similarly, a small push button may send the message that the button is important and it was made small so that it would not to be pushed accidentally. The large size of a button could mean the button has a large force requirement to activate or that the button was meant to be used for frequent, recurring operations.

The labels' main function is to identify the controls. A control can be labeled with a text, a symbol or a pictogram. Labeling may involve description of the control, clues on the direction of the movement or direction for further steps of a task.

Color Coding might be used with the purpose of grouping similar control elements or distinguishing a particular control. In general, the color black is not used for color coding. The colors red or orange can be preferred to prevent accidental use in cases where the control is aimed to be used in an emergency situation.

Resistance refers to the force required to activate the control device. There are four types of resistance: Elastic, static, viscous and inertial. The amount of the controls' resistance determines the feel of the control. Elastic resistance is also called spring loaded. Controls which show elastic resistance return to their original positions when released. Controls showing static resistance oppose the movement in the beginning of the action. Static resistance diminishes dramatically when the control begins to move. Viscous resistance of controls aims to regulate the irregular motions and diminish the rapid movements. Inertial resistance of controls opposes the rapid changes in the motion.

2.4. INTERFACE DESIGN CONSIDERATIONS AND RECOMMENDATIONS REGARDING CONSUMER PRODUCTS

There are different approaches to design guidelines and various suggestions according to the product type and the goal a particular design desires to reach. However, regarding consumer products, there are some basic and common principles in the literature.

Vanderheiden (1997) examines product design considerations as five main groups:

Displays: Input devices which convey information to the user.
Controls: The means which enable interaction between the user and the machine.
Manipulations: Direct manipulations while using the machine such as adding detergent to the washing machine or attaching the hoses of the vacuum cleaner. Manipulations also involve the routine maintenance of the machine.
Documentation: Documents involving procedures to appropriately use the machine.
Safety: Warning alarms for potential dangers and hazards.

In this part, design considerations and recommendations related to consumer appliances are going to be summarized under these five categories.

Displays

- Visual and auditory outputs should be easy to understand (Vanderheiden, 1997).
- Visual displays should be in the visual field of the user. The needs of the users with wheelchairs and users who are shorter than average should also be considered. (Vanderheiden, 1997).
- The visually-impaired user should also have access to important information. Therefore, displays should be multi-sensory: all significant visual information should be conveyed through the auditory and/or tactile senses as well. Visual clues and warnings should be accompanied with a sound warning of a mid-low frequency (Vanderheiden, 1997).
- Auditory displays should be heard clearly (Vanderheiden, 1997).
- For users who can not hear, important auditory information should be conveyed to the user through senses other than hearing (Vanderheiden, 1997).
- The functions of the controls that are not immediately obvious should be identified, (Cushman, 1997).
- Labels should be large, visible and clear to understand (Lindsey, 1999; Vanderheiden, 1997).
- Tactile markings should be easy to find and feel (Lindsey, 1999).

- Sounds and lights can be used to convey any information beyond the basic functions of the display. For example, a timer can beep every half an hour, (Lindsey, 1999).
- If more than one set of information is going to be displayed to the user simultaneously, each information sets should be addressed to a different sense (Dul and Weerdmeester, 2001).
- Sequential tasks should be minimized or have clear clues about the sequencing (Vanderheiden, 1997).
- Displays whose values should be observed together should be in the same horizontal or vertical alignment (Pheasant, 1986; Cushman, 1997).

Controls

- Controls should able to be operated with minimum force, speed and accuracy, taking the needs of the user with the least capacity into consideration (Damon *et al.,* 1966; Lindsey, 1999; Vanderheiden, 1997; Cushman, 1997).
- The number of control elements should be as little as possible for the sake of simplicity (Damon *et al.,* 1966; Vanderheiden, 1997; Cushman, 1997). No complicated or unnecessary actions should be needed to operate the machine (Bridger, 1995).
- Controls should have different forms, shapes, and textures so that they can be distinguished through the senses touch and vision (Damon *et al.,* 1966; Dul and Weerdmeester, 2001). In the case the user who is visually impaired; controls with different forms and textures are a definite requirement to perceive the interface (Vanderheiden, 1997).
- Protruded controls may be preferred to recessed controls. Recessed controls are operated by pushing the button instead of gripping. These kinds of controls may be painful to operate for elderly users (Lindsey, 1999).
- The surfaces of the elements should be non-slippery (Vanderheiden, 1997). Concave buttons and textured controls should be used to prevent slipping. Knurled surfaces provide more friction which allows the control element to be gripped easily (Vanderheiden, 1997; Cushman, 1997).
- Control elements should require natural control motions to operate (Damon *et al.,* 1966; Cushman, 1997). For example, a push button should be designed to be pressed using the thumb or the index finger.
- Controls whose operation involves dual action such as turning and twisting should be avoided. Since these types of controls require continuous pressure and rotation, , using the control element might be painful or impossible for elderly users (Lindsey, 1999).

- Operating the controls should not involve long actions so that the precision and the feeling of the action would not be lost (Damon *et al.,* 1966).
- To prevent accidental activation of the product, critical controls should be emphasized in different ways such as resistance to pushing or turning or by using recessed buttons (Damon *et al.,* 1966; Dul and Weerdmeester, 2001; Cushman, 1997).
- The controls, particularly those which are out of the field of vision during normal operation should have tactile feedbacks (Dul and Weerdmeester, 2001).
- Controls should be easy to reach (Dul and Weerdmeester, 2001; Lindsey, 1999; Vanderheiden, 1997). Control-display layout should be located so that the postural load is minimized (Bridger, 1995).
- The space around individual interface elements, their level of protrusion from the interface and the space between the elements should be large enough for fingers of different sizes (Lindsey, 1999). If the user is visually impaired, the spaces between controls and buttons become more important as it is possible for the user to distinguish the controls and control groups according to the space between specific elements (Vanderheiden, 1997).
- Small controls whose operation requires precise actions should be avoided (Lindsey, 1999).
- If the user has visual impairment, s/he should be able to find the controls easily. For this reason, the location of the control should be physically close to where that control affects. A raised lip or ridge should be placed around the flat panel buttons. Speech recognition technology might also be an option to control the appliances (Vanderheiden, 1997).
- The current position or setting of the controls should be able to be perceived by the visually-impaired users. To attain this goal, the perception of the possible different positions and the current position of the controls should be multi-sensory. Displays which show the current stage of a sequential operation should be addressed to more than a single sense. Absolute reference controls should be preferred over relative controls (Vanderheiden, 1997).
- Users with physical limitations should be able to use appliances without any problems. To attain this goal, the safety interlock to prevent accidental activation should not rely on force. Actions that require applying continuous pressure on a single button should be minimized. The appliance should be suitable to be operated by left or right hand (Vanderheiden, 1997).

Manipulation

- When manipulating the parts of an appliance, such as attaching parts to the appliance or opening and closing sections of it, dual latches which must be used at the same time should be avoided (Vanderheiden, 1997).
- Users should be able to attach and detach the accessories without needing extreme accuracy or force (Lindsey, 1999; Vanderheiden, 1997).
- Appliances should not have small parts that are hard to attach (Lindsey, 1999).
- Latches should be able to be used with closed fists (Vanderheiden, 1997).
- The actions that are required to manipulate the appliance should be clear and easy to understand (Vanderheiden, 1997).

Documentation

- Documentation such as manuals and instructions should be accessible by all users, including users with limitations. The documents should be available in different formats such as the digital form, a hardcopy in large print or in Braille. The documentation should not have sans-serif, small fonts. Basic instructions should also be given on the product, in addition to the documentation (Vanderheiden, 1997).
- Appliances which are used fixed on a surface should have anti-slip bases (Lindsey, 1999).
- Carrying handles of the appliances should be placed appropriately and be comfortable to grip (Lindsey, 1999).

Safety

- All warning and alarms should be multi-sensory. Alarms and hazard indicators should not rely only on visual-perception, i.e. a warning should not be consisting of only lights (Vanderheiden, 1997).

Arrangement of Interface Elements

In addition these categories, there is another category about the arrangement of the interface elements.

McCormick (1993) examines the arrangement of controls and displays on the interface according to four main factors which determine the location of these elements:

- ***Importance:*** Elements with important or critical functions such as safety, performance and emergency indicators should be placed on the most visible field on the interface (Damon *et al.,* 1966; Dul and Weerdmeester, 2001; Pheasant, 1986; Cushman, 1997).

- ***Frequency of use*****:** Elements which are frequently used should be located at the most accessible and visible place on the control panel.

- ***Function:*** Controls with similar functions and their displays should be placed in a logical order and should be grouped together (Dul and Weerdmeester, 2001; Pheasant, 1986; Cushman, 1997). The relation between a control and its display should be obvious (Cushman, 1997).

- ***Sequence of use:*** Controls which are operated in a sequence and their displays should be grouped together (Cushman, 1997; Bridger, 1995).

- During operation, the user's hand should not obstruct the view of an important display element. (Cushman, 1997; Bridger, 1995).
- Labels and the controls they belong to should be in the same spatial relation throughout the control panel (Cushman, 1997).
- The work load on the right and the left hands should be equal (Cushman, 1997).
- Controls and displays which are grouped together because they belong to similar functions, should be distinguished with different methods to prevent the users from mixing them up (Cushman, 1997).
- When a control is adjusted, its display should move in a direction consistent with the control (Cushman, 1997).

CHAPTER III

VISUALLY IMPAIRED AND MACHINE INTERACTION

In the first chapter, research questions were presented as follows:

Does the product fulfill its functions adequately?

When functioning, is the communication between the product and the user satisfactory?

As emphasized in the previous chapter, in the interaction process, the perception of interface basically relies on the visual sensation. Accordingly, the question “How does interaction between a visually-impaired user and a product depending on visual clues to operate takes place?” comes to mind. From this point, with respect to the previous questions, two more questions can be derived:

Does the user who has visual impairment utilize the product with full functionality?

What kind of communication occurs between the product, and the user with visual impairment and what are the weak points in this communication?

Furthermore, another question might be added with the purpose of understanding how a user reacts to possible problems:

Can the user compensate for and recover if there is a break in the communication loop?

At the end of this study, it is expected to find answers to these questions. After the problematic points that may cause the break down of the interaction process between the visually-impaired user and the machine are determined, design suggestions will be given to minimize the effect of complications that may arise during operation.

3.1. AIM OF THE STUDY

The aim of the study is to describe the relationship between a user with visual impairment and the interface of electrical consumer products. Accordingly, the study aims to figure out the problematic points during the interaction process and offers design suggestions so that

users with visual impairment can use their electrical domestic products adequately and as independently as possible.

3.2. METHODOLOGY

The research involves the study of tasks performed by ten non-sighted, female users. The tasks consist of operating three electrical household products: A washing machine, a vacuum cleaner and an iron. When conducting these tasks, two descriptive methods, observation and interview, are applied.

Observations were carried out in the homes of the users with their appliances. The aim was to observe and to understand the behavior and reactions of the visually-impaired user when operating the device. Therefore, home observations were preferred so that users' natural reactions and behaviors could be observed. Each observation session included the operation of the three products listed and took about 30-40 minutes.

After observation, an interview was conducted. The interviews were not recorded on tape or camera. Instead, the questions and the answers were recorded manually by taking notes. The reason for choosing to record the interview manually was to make the users more comfortable and create relaxed atmosphere in which questions could be directed as in a casual conversation. Lastly, the goal of the interview was to get information about the operation of the products from the users' point of view.

Observationm

In the test, informal home observations were used. The reasons why home observations were conducted are considerations regarding the reliability of the results. To assess the performance of a user with visual impairment, a natural environment, such as her home, is necessary. A familiar environment prevents the user from being anxious and uncomfortable so observations are close to the real situations that users experience everyday.

During the observations, a video camera used to provide a documentation to analyze later. In the analysis stage, checklists were used with the purpose of treating each observation equally and for making the analysis easier.

Checklists for Observation

The checklists aim to provide a guideline, a road map for both conducting the observations and evaluating the results. They were prepared according to the typical task analysis of the products observed and eventually, three different checklists were composed for three

mdifferent products. All three checklists contained some common articles such as the perception of displays and controls, the errors made and difficulties experienced by the user, the overall rating of the performance regarding that task and the thoughts and suggestions of the users. Other articles were derived from the task analysis of that product.

Observations were examined under six or seven sections. Each section aims to find out the habits and common behaviors of users and the problems they experience. Observation checklists can be found in Appendix A1, A2 and A3.

Interviews

After the observations, a semi-structured interview was conducted with the purpose of obtaining suggestions from users to improve their communication with the machine and understanding the problems of the users at firsthand. While this data might be used as supplement to the observation results, it might also be used to form design suggestions about electrical consumer products.

Interview Questions

Interview questions can be divided into two groups according to when they were directed to the user. During the interviews same questions were used for the washing machine, the vacuum cleaner and the iron.

The first group of questions was asked before conducting the observation. These questions were about how the product was purchased and any future plans about that product. The questions aimed to get an idea on whether the user purchased that product based on an informed selection or not and whether she thought of replacing the product with a different one because she was not satisfied with the product.

The second group of questions was asked after the user demonstrated how she used the product. At this stage the user had recalled her past experiences with the product and provided more satisfactory answers. This group of questions was more specific: they included questions such as which interface elements were satisfactory or unsatisfactory to the user. Eventually, the last article asked the opinion of the user on how the design of the product should be so that it can be used properly by visually-impaired users. In this crucial question, it was intended to extract some clues about which points should be taken into consideration when designing the interface. Interview questions can be found in Appendix B.

3.3. SAMPLING

The study was conducted with ten female users with visual impairments. Males with visual impairment were not included in the study for two reasons: First, it was intended to eliminate the differences due to gender. Second, females, especially in Turkey, deal with domestic products more frequently than males. Therefore, a group who is familiar with electrical household products was chosen.

The average age of the sample group was 35.5; the oldest three users were in their early 40's. Others vary between the ages 30 and 35.

Five of the users[2] have attended or graduated from a university, one user is a high school graduate and the remaining four users have elementary school education.

The users had different levels of vision loss. Three levels of impairment were encountered during the study: Blindness with no light sensation, blindness with some light sensation and visual impairment with 10% of sight. Four of the users had no light sensation, four of them had some sensation of light and two users had visual impairment with 10% of sight.

Table 3-1: User Profiles

USERS	SIGHT	HISTORY OF IMPAIREMENT	AGE	EDUCATION	EDUCATION FOR THE BLIND	BRAILLE
USER A	0 %	No Information	42	University Graduate	Yes	Yes
USER B	0 %	Since childhood (No Information about when)	35	University Graduate	Yes	Yes
USER C	Light Sensation	Congenital	30	University Graduate	Yes	Yes
USER D	0 %	Congenital	35	Primary Education	Yes	Yes
USER E	10 %	Since 1999	31	Primary Education	No	No
USER F	0 %	Congenital	45	University Dropout	Yes	Yes
USER G	Light Sensation	No Information	34	Elementary Education	Yes	Yes
USER H	Light Sensation	Since 1984	41	Primary Education	Yes	Yes
USER I	Light Sensation	No Information	34	High School	Yes	Yes
USER J	10 % and farsighted	No Information	31	University Graduate	Yes	Yes

[2] One of these five users attended a university, she did not get a degree. Despite this, this user is treated as having a university degree since she had a partial university education.

Selection of Product Groups to be Tested

When deciding on which products to study the primary concern was to choose products that were used by a range of people as wide as possible. Furthermore, the frequency of use was also significant. These two variables are important in determining how vital the product is in a household daily life.

After consideration, three products were selected according to the previous criteria: The washing machine, the vacuum cleaner and the iron.

The washing machine was selected since it is the product which is affected from technologic innovations in terms of capability and design of control panel most.

The vacuum cleaner was chosen to observe the spatial relationship between the appliance and the user with visual impairment.

Lastly, the iron was selected with the purpose of observing users with no sight dealing with a device which is potentially dangerous. Moreover, in the case of the iron, the spatial relationship between the product and user can be observed as well.

In addition to these reasons, the products chosen require different controls and procedures to operate and this variation in operation avoids the possible shortcomings of observing a single consumer product.

Limitations

The limitations experienced during observation can be classified under two main groups:

Limitations caused by the nature of the research: During the observation, the users were not given a list of the tasks they should perform. This decision was made with purpose of not affecting the user's natural behavior patterns. Therefore, while performing the task, if the user did not attempt to use a particular function of the product, she could not be asked to use that function directly. Instead of directing the user to use that control, other approaches were chosen to observe usage of the control. For example, in the observation of the iron, the question "At which level of heat do you use your iron?" was chosen instead of "Could you show me how you adjust the temperature selector?" In this example, after the question was directed, the user was willing to show at which level the temperature was set. However, if a user was determined not to use a particular control, the observer did not insist that the user used that control.

Limitations related to the products: In some situations, a user could not use a particular function of her device because that function of the product was not operational at the time of observation. For example, User I could not operate her iron's spraying function because the function was broken.

3.4. ANALYSES OF THE TESTS

3.4.1. Observation Findings for Washing Machines

The interface analyses of the washing machines operated by the users are presented in the Appendix C.1. A summary of the observation data tabulated according to the users and stages of the tasks can be found in the Appendix C.2. The summarized data of the interviews can be found in the Appendix C.3.

Loading

During the observation, five out of ten users were observed loading clothes into the washer tank. These users checked the amount of laundry in the washing machine using the same method: They first loaded the laundry without any difficulty, and then checked the amount of laundry in the washer by touch. No hesitation was observed in the stage of loading the washer machine except for User C. User C hesitated whether the door was shut or not and pushed the washer door to ensure it was shut.

Figure 3-1: User C closing the door of the washer.

Adding the Detergent

While adding the detergent and the fabric softener, users chose similar methods. No user had difficulty locating the detergent dispenser. In fact, all users located the detergent dispenser almost immediately. With the exception of User A, users did not experience any confusion deciding which dispenser was for the detergent and which dispenser was for the

fabric softener. User A hesitated then added the detergent and the fabric softener by guessing.

Figure 3-2: User C adding detergent into the dispenser

Figure 3-3: User F checking the amount of detergent with her fingers.

While adding the detergent, most users used a cup to measure the amount of detergent. User C had no cup and added an arbitrary amount of detergent. After adding the detergent, users used their fingers to check the level of the detergent in the dispenser.

Setting the Washing Program

While setting the washing program, users preferred different methods depending on the design of the control. Nevertheless, it was obvious that they used information that was previously explained to them. Using this information, users, except for Users A, D and I, could successfully set the program. Three different methods were observed while setting the program. Users A, C and F counted the positions or click sounds to set the selector. Users B and H used the notches or small wooden sticks they had added around and over the rotary selector. Users E and G had a bar on their machines' program selector and they could set the program with reference to the position of the bar.


Figure 3-4: User F setting the water temperature.

The first group, consisting of Users A, C and F counted the positions starting from the initial position of the selector. While determining the position of the selector, users benefited from various clues such as marks around the selector or on the starting point or the position of the bar on the selector. User A rotated the bar so that it is vertical, then rotated the selector clockwise and counted the number of clicks to set the program to “Program F”. User C had a notch on the initial point of the selector that had a clockwise and discrete movement. At first, she set the mark at vertical position, which was the initial position of the selector. Then, in order to select the program type, she rotated the selector and counted the positions and set the selector at the seventh position. User F hesitated while using the program selector since she had not used the selector for some time. In spite of this setback, she successfully accomplished this step of the task after getting help: After being told that the status of the selector was “Program D”, she could turn the selector to “Program F”.


Figure 3-5: User H setting the program selector.

The second group of users, consisting of Users B and H, used the program selector by aligning the marks. They had previously attached one or more sticks or notches on the selector. User B utilized a notch on the program selector, which was previously made by her. She understood the selector was at the short program when the notch on the selector was parallel with the mark on the program display. During the interview, User B claimed that the

program and the temperature knobs would be impossible to operate if she had not marked them by scratching over. User H also benefited from sticks which she had previously attached around the rotary knob and on the symbol above the selector. There were two distinct sticks which corresponded to programs A and D over the rotary knob. User H selected the “Program D” by aligning the short stick on the selector with stick on the symbol.

For the third group of users, consisting of Users E and G, the position of the bar on the rotary knob was the important factor to determine the position of selector. User E set the bar on the selector to a vertical position. She explained that she knew that the vertical position of the bar corresponded to “Program A” and she uses that program most of the time. Similarly, User G had the knowledge that when the bar is vertical, that is when the mark on the bar is at the 12 o’clock position, the washing machine is set to “Program A”. Furthermore, according to information that was given to her, she stated that at the 6 o’clock position, the washing machine is set to “Program D”. During the interview, User G stated that she appreciated her machine’s program and temperature selectors having raised marks. User G did not report any difficulties regarding the operation of the control panel.


Figure 3-6: User E setting the program selector.

The remaining users, Users I and D, could not complete setting the program successfully because they did not know which position of the rotary knob corresponded to which program. User D said that she had thought of setting sticks over the program selector while User I preferred to ask for help when determining the current position of the selector. During the interviews, both User I and User D stated that their machines’ program and temperature selectors were not useful due to lack of haptic clue to provide accurate control.


Figure 3-7: User J setting the water temperature.

Lastly, User J's situation was different. Since she had some vision and the labels of dial were big enough, she managed to read the letter around the program selector. User J read the letter "D", and then by referencing "D", she rotated the knob clockwise until the washer machine was set to "Program A".

Setting the Water Temperature and Spinning Velocity

While selecting the water temperature and spinning velocity, most users employed same procedure they used while setting the program. However, some users employed a different method. For example, User A decided the position of the selector according to the rotation of the bar. This user explained that she knew that the water temperature was set to 30° C when the bar on the selector is in horizontal position. Moreover, she also knew the water temperature was set to 60° C when the bar on the selector is in vertical position. During the observation, she decided to set the temperature to 45° C by setting the bar somewhere between the vertical and the horizontal positions. While setting the temperature, User A complained that she had to set the temperature to approximate values as she had no way of knowing any of the values precisely except for 30 °C, 60 °C and 90 °C. User F used a method similar to User A's to set the temperature.


Figure 3-8: User F setting the water temperature.

It was observed that the vertical or horizontal position of the bar or the mark on the selector gives a clue about the value the selector indicates. Users A, B, E, F, G and H set the water temperature and spinning velocity with reference to the position of the bar or the notches.

Figure 3-9: User H pushing power button.

During the interviews, Users A and G who had bars on water temperature and washing program knobs, reported that those bars make the machine easier to use. Users H and J also commented on the selectors of their machines but they stressed different points such as protruded selectors and large labels. Those users said that protruded selectors and large labels make easy to use their washing machines. User E found her machine's selectors easy to use. However, she added that this may be because she bought the machine when she had sight and she was already familiar with the controls when she lost her sight.

Using Push Buttons

Users were rarely observed using push buttons. Except for Users A and I, users pushed buttons only to start the washing machine. The machines of Users A and I did not have a power on/off button, and thus those users were not observed operating a button at all. User C was the only user who chose a washing option. Those users who did push a button perceived the location of the button by moving their fingers over the button group on the interface and located the correct button by referencing its position among other buttons. For example, to run the machine, User B moved her fingers over the buttons and she felt the buttons as group. Then, she pushed the first button from left, among four identical buttons. The user was not observed operating the other three buttons. Regarding optional push-buttons, users reported that they did not prefer to use these buttons because they did know the exact functions. Furthermore, User C stated that she could not utilize all the functions of her machine since the user manual was not in Braille.

Evaluation

None of the washing machines observed in this study had a digital display or a touch screen. All had similar control interfaces in terms of arrangement of control and display elements, functions and style of knobs. It is likely that the users observed in this study preferred to purchase washing machines with less controls and displays intentionally because of their visual impairment.

While operating washing machine, no user had any difficulty locating the detergent case. This was because all users knew which side the case and its handle were at. Therefore, all users gripped the handle of the case easily at their initial attempt.

All users who were observed when loading the tank used their fingers to check the amount of the laundry in the washer tank and the level of the detergent or the fabric softener. User B used a scale cup to add the detergent, so she did not have to check the level of the detergent by using her fingers.

Regarding the water temperature and the program selection controls, three different methods were observed. The controls of the first group of users had a bar on the selector knob and the users had not performed any modifications on the selectors. The users operated the water temperature and the program selectors according to the orientation of these bars. For instance, in one case, the horizontal orientation of the bar provided the information that the water temperature was set to 30 °C to the user.

The second group of users had machines with rotary selectors in a circular shape, lacking any tactile references. These users had modified these knobs in order to form one or more reference points. These modifications involved making tactile marks with different methods. For example, User B formed notches on the knobs while User H attached toothpicks with a sticky tape on and around the knobs. The second group of users used the marks they formed as reference points and operated their machines similarly to the first group of users. The orientation of the notches or marks provided information about the value the knob pointed at.

Third group of users had machines with either a raised bar on the knobs or a circular knob. Unlike the users from previous groups, users of the third group counted the possible positions of the knobs. They got auditory feedback by listening to the click sound generated by the knob when the knob was in a position or the slight resistance to movement the knob showed when the knob was in a position. Nevertheless, the users had to get the knob to the initial position to be able to count positions accurately. It was observed that all users know which direction they should rotate to move the selector knob to its initial position.

When all three groups of users are considered, it seemed that in order to operate the machine, all the users use knowledge which is learned previously; when the machine was bought. This observation was further strengthened through the comments Users A, F and I made while operating the machine. However, these users could not set the program without help because they needed to know the current position of the selector to be able to follow the set of actions they have memorized.

All users except for User C did not use any of the optional buttons. Although these buttons are easy to locate, the visual labels of the buttons provide a challenge for users without sight.

The interviews yielded information that was strongly related to the individual experiences of the user being interviewed. The users were inspired by their problems and their answers included many ideas regarding the ideal design criteria for the appliance. Their input as a modification or comment, in fact, has become a step in the solution of the problems.

An idea proposed by five of the users was particularly interesting. These users asserted their belief that user manuals printed in the Braillle Alphabet would make controls easier to use. They claimed that a manual which explains how to use the machine for the visually-challenged makes such users independent of other people. Therefore, they could use all the functions of their machines without needing help.

Apart from improving user manuals, common suggestions included auditory feedbacks from the controls and haptic clues on the selectors and buttons. With respect to auditory feedbacks, four users stated they think that selectors could involve spoken messages and those messages could relay the information about the value that the selector is currently pointing at. Furthermore, one of these four users stated that different auditory signals generated at each position of the controls would be useful in setting the selectors.

Regarding haptic clues, all users had similar ideas. They reported that a single raised mark either on or around the selector is useless. Instead, a pair of raised marks or a letter on and around the selector would make the use of the selector much easier, as the user would be able to match them.

3.4.2. Observation Findings for Vacuum Cleaners

The interface analyses of the vacuum cleaners operated by the users are presented in the Appendix D.1. A summary of the observation data tabulated according to the users and stages of the tasks can be found in the Appendix D.2. The summarized data of the interviews can be found in the Appendix D.3.

Setting

Depending on the physical size of the vacuum cleaner, three users were observed having trouble moving the vacuum cleaners around. Users E, F and H had difficulty when carrying their cleaners since their machines were comparatively larger and heavier than other users' vacuum cleaners.

Figure 3-10: User F carrying her vacuum cleaner.

User F spent a considerable amount of time to set up the vacuum cleaner. First, she struggled to attach the parts such as hose, brush and hose of wet vacuuming together, a feat which took a few minutes. Then, she filled the cleaner's tank with water. Filling the tank and placing it in the vacuum cleaner was not particularly hard for her. Nevertheless, fixing the clips to the water tank was quite difficult. During the interview, User G stated that she had difficulty setting up and breaking down the hose and the suction wand of the vacuum cleaner because the parts did not fit each other perfectly. User A complained about her vacuum cleaner's lid of the dustbag that was too easy to take apart and that proved to be a problem during operation.

Figure 3-11: User D Unwinding the Cable.

While unwinding the power cord, two different situations were encountered; Users B, C, F and I kept the cord unwound while others kept it wound so these users were not observed unwinding the power cord. In both cases, users were not observed having any problem related to the power cable.

Turning on

When turning the vacuum cleaner on, all users except User J could accomplish this task step at their first attempt. User J pushed the wrong button – the one for unwinding the cable. When she received no feedback, she tried to push it one more time. Then she realized that was the wrong button and immediately pushed the correct button. User J did not have any difficulty when turning off the vacuum cleaner. After operating the machine, User J explained the reason for her mix-up: The vacuum cleaner she was observed with was different than the model she was used to. She was using a different vacuum cleaner because her vacuum cleaner had broken down a few days ago.

As mentioned in the interviews, for rest of the users, perception and usage of buttons and switches were not a problem. For locating the power buttons, these users pursued similar methods.

Figure 3-12: User H pushing the power button.

Users E, F, G and H had bulky vacuum cleaners and found the correct button or switch with reference to the position of the device. User E held the handle on top of the vacuum cleaner, pulled it to her left and turned it so that hose socket faced towards the front. In this position, she immediately pushed the switch which was closer to her. Similarly, User G found the location of the button with reference to her position in relation to the vacuum cleaner. When the vacuum cleaner was on her left side and in such a position that the suction hose looked forward, the user knew that the button at her left was power on/off button.

Figure 3-13: User G pushing the power button.

The other users located the controls on the vacuum cleaner according to the controls' positions. For example, User B found the power button by moving her right hand quickly over the surface of the cleaner. After locating the correct button, she pushed it with her thumb. Similarly, User D first figured out where the vacuum cleaner was located in the room and once she found it, she searched for the power button by moving her hand over the device. After locating the button, she pushed it with the palm of her left hand strongly. The actions of User I were also similar. User I had a vacuum cleaner with five buttons. She found the control panel of the machine at first attempt. Then she touched somewhere between middle and the left side of the vacuum cleaner. Then, she moved her fingers to the right side of the vacuum cleaner. Finally, she pushed the large, foot button with her two fingers.


Figure 3-14: User B pushing the power button.

Adjusting Suction Power

During observation, no user, except for User A and User E was observed adjusting suction power of the vacuum cleaner. This was due to two reasons. First, Users B, C, F and G preferred not to change the previous suction setting even though they could show how to change the suction level. Second, other users' vacuum cleaners had a constant suction level.

Figure 3-15: User A adjusting suction power.

The first group of users benefited primarily from the noise of the motor of the vacuum cleaner as a feedback of suction power. In addition, these users knew which direction they had to turn the control knob to increase or to decrease the suction power. The exception was User A, who had Bosch Sphera. She had trouble while adjusting the suction power selector because she could not firmly grip the selector. Similarly, User J who had the same vacuum cleaner, reported that she has difficulty adjusting the suction power selector because she can not grip the selector properly.

Although the suction adjustment controls of some of the vacuum cleaners are rotary knobs without any tactile markings, the users did not experience any difficulty since the noise of the motor functioned as feedback. Other vacuum cleaners had single or two-level suction power modes which were controlled by a push button or rocker switches.

Vacuuming

No unusual or unexpected behavior was observed during vacuuming. The users showed variations in some aspects. Users A, E and H vacuumed while bending so that they could constantly check if the floor was properly cleaned or not. Other users vacuumed the floor standing straight. Users were observed to move the suction wand in three different patterns. Users A, C, E, F H and I used the suction wand in a repeated back and forth motion. The actions of Users D and J were linear and continuous. Lastly, User G used the wand in circular movements.


Figure 3-16: User E vacuuming.


Figure 3-17: User F vacuuming.

Apart from these variations, during the interview, User H stated that during vacuuming, she could not hear anything else than the vacuum cleaner's motor because the motor noise of her vacuum cleaner was very loud. Therefore, during vacuuming, her perception of the environment was seriously interrupted by noise. In addition, User B pointed out the absence of an auditory signal to alert user that the dustbag is full.

Evaluation

An interesting finding came up when the model of the cleaners were same or very similar. Three of the vacuum cleaners observed were similar models of the same brand. The main difference between these models was the suction power; otherwise the appearance and buttons of the vacuum cleaners were identical. The users who owned these vacuum cleaners stated that they chose that model consciously. They were all very satisfied with their vacuum cleaners since it was simple to operate, light and powerful.

The vacuum cleaners that can clean dry or wet surfaces are similar in terms of the number and the simplicity of controls. They all have only two controls, one of which is the power button.

In the case where the vacuum cleaner has two identical buttons, users know which button is for power on/off and can push it without any hesitation. It was observed that, in this situation, the position of the vacuum cleaner according to the body of the user plays a major role. This is because the user can construct a spatial map in her mind and she can find out the correct button to push with reference to the position of the cleaner. For example, when a user was asked how she knew which button was power on/off, she unconsciously answered as “This is the one, the one close to me.” Namely, if the vacuum cleaner is at the left side of her and the vacuum cleaner’s suction socket faces forth, and then the button which is close to her is the power on/off. As was observed in washing machines, in vacuum cleaners, the suction adjustment switch is used by relying on learnt knowledge about relationship between the rotation of the knob and the amount of suction provided. Apart from this, all users reported that they understood the power of the suction according to the motor’s noise.

During vacuuming, it was observed that Users A, E and H vacuumed while they bent over the surface they were vacuuming. On the other hand, other users vacuumed while standing straight. No conclusive result can be obtained from this data. It is possible to say the reason of bending over while vacuuming is related with the concerns about cleaning.

Major differences among users’ performance was not observed when operating vacuum cleaners Furthermore, the task poses no problem to someone who is experienced with it.

3.4.3. Observation Findings for Irons

The interface analyses of the irons operated by the users are presented in the Appendix E.1. A summary of the observation data tabulated according to the users and stages of the tasks can be found in the Appendix E.2. The summarized data of the interviews can be found in the Appendix E.3.

Setting up

While preparing for ironing, the first step was setting the ironing boards up. Users B, C and G were not observed setting up ironing boards as Users B and C had already set the boards up before and User G could not use her ironing board because the board was not available during the observation. Users E and I got assistance from their children to unfold the board. Users A, D, F, H and J did not have any problem unfolding and setting up the ironing board without any help.

Figure 3-18: User D setting the ironing board.

Filling the Water Tank

Users A, G, H and I, were not observed filling water into the water tank for various reasons. Users A and G had already water in the water tank. However, User A kindly demonstrated how she filled the tank. She detached the water tank from the main body of the iron. She stated that because the tank is detachable from the iron, filling it is an easy task - she could fill the water tank like she filled a regular glass. The iron used by User H had no steam function and the spraying function of User I's iron was broken.

Figure 3-19: User J filling the water tank.

Most users completed the task of filing the water tank successfully. Users C, E and F were observed spilling some of the water while filling the tank.

Figure 3-20: User B filling the water tank.

Users took hold of the iron and located the water fill opening at first attempt. They poured the water with their hands they held the iron with the other hand. Being left or right handed determined which hand they would use to pour the water and to hold the iron.

Most users held their index fingers or thumbs in the water fill opening to perceive the level of the water. Users E and F, who did not keep her finger in the water fill opening, caused an overflow.

Adjusting the Temperature

While setting the temperature of the iron, all users did not actively adjust the temperature because they used their irons set at a constant temperature. However, upon request, they showed how to adjust the temperature. For example, User A explained that she generally used the same temperature setting. While demonstrating how to adjust the temperature level, she first turned the temperature selector clockwise until the iron was turned off. She knew that rotating the selector clockwise turns off the iron and rotating the selector counter-clockwise turns the iron on and increases the temperature. She also stated that she irons with the selector set at an average value between the maximum and the minimum. In a similar manner, the other users were also observed using knowledge that was previously explained to them about the relationship between the selector's direction of rotation and the level of temperature setting to set the temperature. Moreover, Users A, F, I and J remarked that they checked the current temperature of the iron by touching the soleplate gently.

Figure 3-21: User J controlling the heat of the soleplate.

Figure 3-22: User H adjusting the temperature.

Although the irons of users, except for Users C, H and I, had raised marks around the selector to indicate the position of the selector, the users could not benefit from this. The users stated that the raised marks around the selector were of no help without a raised mark on the selector to indicate the current alignment of the selector. For this reason, marks around the selector were useless for the users. On the other hand, the iron of User H did not have any raised marks, neither around nor over the selector. The iron of User I did have a pointer on the selector but since there were not any raised marks around the selector, she, too, could not adjust the temperature accurately. User C's iron had a slide switch and there were not any raised marks or any symbols around the switch to indicate the temperature level. Therefore, User C was not observed adjusting the slider. Lastly, User E was not observed using the temperature selector. She said that her daughter or husband set the selector because she did not know at which position the selector should be according to the fabric type.

Spraying and Steaming

No users were observed using the spraying function of their iron. Yet, Users A, C, E, G and J, were observed using steaming function. While Users C, G and J were observed just turning on the steaming, Users A and E changed the power of steam during ironing.


Figure 3-23: User C adjusting the steaming.

User A first turned the selector clockwise until the selector did not move any more. She knew that this was the initial position of the selector. Next, she turned it counter-clockwise slightly to set the steam at first level. She also noted that she could understand the current temperature of the iron due to the steam function because the steam function does not work below a certain temperature.


Figure 3-24: User E turning on the steam.

Adjusting the steam power of User E's iron was simple. She pushed the button over the handle by her thumb to increase the steam.

Ironing

Ironing styles showed variation depending on the personal habits and being left or right handed. Differences in how the users moved the iron on fabric were particularly obvious. For example, while User B ironed the t-shirt with small movements with nose of the iron moving to left and right, User C moved the iron on the part of the cloth linearly and randomly. When straightening and stretching the laundry, User C benefited from her edge of the board being narrower.


Figure 3-25: User B ironing.

Because the surface User G ironed on was narrow and relatively short she was observed ironing by moving the iron back and forth while moving it gradually in a horizontal direction. She only used right hand when ironing and consequently, the t-shirt was wrinkled because of the nose of the iron.


Figure 3-26: User H ironing.

The ironing style of User H was different when compared to the others. Duration of ironing was relatively much longer because she spread out a damp fabric upon the shirt to be ironed to prevent the shirt from burning. She moved the iron on the fabric in a random fashion.

All the users, except for User I, completed ironing without any problems. While User I was ironing, her mother interfered because the printing of the t-shirt was damaged by the iron. User I's mother turned the t-shirt inside-out, checked the value on the temperature selector of the iron, noted that the selector was set at a value close to the maximum, changed the temperature setting and gave the iron to User I again.

Evaluation

During the observations, major differences were not seen among users. The users showed some variation in details such as using their left or right hands while ironing, using their index finger or thumb to control the water level in water tank and in their styles of ironing. These differences did not affect how well they performed ironing. Nevertheless, this does not necessarily mean that the performance of all users were satisfactory. None of the users attempted to adjust the temperature of the iron. They remarked that they have difficulty in setting the temperature of the iron so they just keep the knob at an average value.

In the preparation stage, setting up the ironing board did not prove to be a problem. Yet, while filling water into the water tank of the iron, some users spilled the water over. There are two possible reasons for spilling the water. First, the users did not use their fingers to check the level of water. Second, the water fill opening is too narrow and water would be spilled over in any case.

Although almost all of the irons observed have some raised marks around the temperature knobs, the users could not benefit from these marks because the irons lacked the necessary marks on the temperature knobs which would supply the haptic clues needed to allow the users to deduct the current setting of the knob. Correspondingly, during interviews, all users emphasized that they can not use the temperature selector of their irons. In addition, they also think that the temperature selector is the most important component of the iron which can be designed considering the needs of non-sighted users. However, each user came with different suggestions to solve the temperature selector problem. Users A and F said that there could be auditory signals. The selector could generate a click sound on each position instead of the current continuous rattle that is heard as the knob is turned. User I suggested using recorded messages which inform the users about the setting of the steam power and temperature of the iron. Users B and G said different push buttons could be used for different levels of temperature. The other users mentioned raised letters and marks around the selectors.

CONCLUSION

The last chapter of this study is divided into two sections. The first section is an evaluation where the research questions posed at the beginning of the third chapter are answered and the problematic issues that occur in the communication between the visually-impaired user and the appliance revealed during the study are explained. The issues are organized according to the observational findings and users' comments and complaints about their products. In the second section, following a summary of the previous chapters, the study is concluded with a list of design suggestions.

4.1. THE VISUALLY-IMPAIRED USER AND OPERATING THE PRODUCT

A visually-impaired user can operate the product as long as she is familiar with that product. This familiarity requirement can be satisfied my meeting two conditions: First, the user must be explained the interface of the product and how to start the product up. Therefore, the user should be informed about the interface and operating sequence by a sighted person. Second, because the period of learning the interface and how to operate the machine is significantly longer for a non-sighted user when compared to a sighted user, the non-sighted user must use the product for a longer time before gaining enough experience to operate the product comfortably.

The study revealed that appliances with digital displays can not be used even if they are explained to the visually-impaired user by a sighted person. Appliances with digital displays communicate with the user through a screen that lacks both tactile and haptic clues. Such an interface is not possible to operate for users with visual impairment. Therefore, it is possible to say that the visually-impaired user can use an electrical appliance without digital display or touch screen.

Even when the visually-impaired user can operate an appliance, she can only use the basic functions. In other words, the user cannot benefit from the full functionality of the appliance. Visually-impaired users tend to minimize the number of tasks and controls used because they either are not aware of all the functions of the appliance or do not know how to operate them. To conclude, the visually-impaired user can operate the electrical appliance at a basic level, rather than employing all of the product's functionality.

4.2. COMMUNICATION BETWEEN THE PRODUCT AND THE USER WITH VISUAL IMPAIRMENT

The study proved that communication between the visually-impaired user and the product relies on the tactile and auditory clues and references.

Unlike a sighted user, a visually-impaired user interacts with the whole physical surface of her appliance. Any tactile reference may help the visually-impaired user when using the device. For example, the location of the hose socket on a vacuum cleaner provides a reference for the positioning of the buttons. Visually-impaired users perceive the control elements as a whole and individual controls as a part of that whole. For this reason, it is important that individual control elements are distinguishable with their form and/or surface texture.

The direction of rotation of the control elements plays a major role when a visually-impaired user communicates with an interface. To adjust a knob, they memorize the relationship between the direction of rotation and the value pointed by the knob. Rotating the knob either clockwise or counter-clockwise is the key to set a value. The orientation of the bar on the knob may also assist the user adjusting the knob.

For the visually-impaired users observed, contrary to sighted users, minor auditory signals such as click sounds are very important clues in communicating with the device. Other auditory clues, such as the noise of the motor of the appliance also provide a feedback when starting up the appliance and during its operation.

4.3. WEAK POINTS IN THE COMMUNICATION

Throughout the observations, weak points in the communication between a visually-impaired user and the appliance are caused mainly because haptic and auditory clues and references are completely absent or the clues and references present are insufficient. Apart from this, a major weakness arises when the visually-impaired user first encounters the appliance. A visually-impaired user can not start communicating with the appliance even if the product has sufficient haptic and auditory clues and references. She needs guidance for the first use.

According to the findings of this study, involving observations of thirty appliances in total, problematic issues regarding the interfaces of the products can be classified under two main titles. The first title includes the problematic issues encountered throughout the study in general. The second title includes the problematic issues encountered during the study of a particular product group.

4.3.1. Problematic Issues in General

The general problems experienced can be examined in four different groups:

Rotary Selectors with More Than Six Positions and Continuous Rotary Knobs

Selectors and knobs without tactile marks on and around them make it difficult or impossible for a visually-impaired user to perform the related task. Visual labels provided for knobs and selectors are not large enough to be read by a user with 10% sight.

If the selector has more than six positions, it becomes harder for the users to count the positions. In addition, as the number of positions increase the click sounds the selector makes become a less effective method to provide auditory feedback.

In cases when the position of selector is related with the number of clicks it makes during rotation, the user may forget or miscount the number of clicks.

- The program selector keeps rotating automatically during a washing cycle. Therefore, the user has no way of knowing what the position of the knob is after the washing cycle is completed.

- The bar on the selector or knob allows the users to grip the control. However, the presence of a bar does not ensure that all the values and the positions of the knob can be used easily. If there is no mark on the bar, it is not possible to set the control accurately.

- Effectively, rotary selectors and knobs can only be used to set the control to two or three values or positions. For example, when we consider the program selector knobs of washing machines, only programs A and D are used commonly. With respect to the temperature selector of the same appliance, temperatures apart from 30° C, 60° C and 90° C are not used. Similarly, the temperature selectors of irons are kept on at average temperature.

Push Buttons and Rocker Switches

- Use of optional buttons by visually-impaired users is rare. During the observations, only a few users operated any optional buttons. The users stated that they do not know the functions of optional buttons. Furthermore, the buttons were labeled visually and it was impossible for a visually-impaired user to distinguish the functions of identical switches.

- Although no complication is observed when only two identical buttons are placed on the interface; as the number of identical buttons or switches increase, the users tend to confuse the buttons or switches.

- Moreover, successful operation in the situation when there are two identical buttons on the interface relies on the user's experience with the product. If the user is operating the product for the first time, she is likely to be confused.

User manuals

For a visually-impaired user to use an appliance properly, she must be informed about the controls before the first use. Usually, a person from the technical service department for the product instructs the user about the appliance. However, this instruction covers only the basic functions of the product. Therefore, the user cannot use all the functions of the product adequately. The majority of the users stated that the lack of a manual in Braille intended for the non-sighted makes non-sighted users dependent on sighted people. Furthermore, the user can not benefit from all functions of her appliance.

Plugging

While plugging is not directly related to the interface of a product, during the observations, it was seen that plugging is a difficult task for the users. Most of the users spent a lot of time plugging the device when compared to the entire duration of operation. The visually-impaired users can not match the contacts of the plug and the holes of the socket at first attempt. In brief, plugging is one of the common issues experienced by non-sighted users.

4.3.2. Problematic Issues Specific to Product Group

- For a dry and wet vacuum cleaner, moving the appliance and setting it up is difficult as the appliance is bulky.

- Attaching the parts of the vacuum cleaner together is a difficult task.

- Because there is no auditory signal to indicate that the dustbag is full, the user can not understand if the dustbag is full or not.

- Users have no way of checking if the surface they are working on is properly cleaned or not. Also, there is no suitable brush to clean the corners.

- The motor of the vacuum cleaner is very noisy and this prevents the user from hearing other sounds in the environment.

- The method for checking the temperature of the iron is dangerous. Since there are no feedbacks or clues for the user to comprehend the iron's temperature, the user has to check the temperature by touching the soleplate.

- The narrow water fill opening of the steam iron causes the users to spill of water while filling the water tank.

4.4. HOW THE VISUALLY-IMPAIRED USER RECOVERS IF THERE IS A BREAK IN THE COMMUNICATION LOOP

According to the study, a visually-impaired user figures out what she needs to know or modify when she first uses the appliance. After understanding possible breaks in the communication loop, the user can compensate in different ways. Users may choose to modify the interface elements or choose taking assistance from a sighted person in some steps of the task.

Visually-impaired users compensate for breaks in communication during the interaction via modification of interface elements or by memorizing movements and positions of controls. The user might modify the interface with the purpose of providing a reference point for rotary knobs or labeling the controls. The most common modification encountered is attaching a matchstick or a toothpick to create a tactile clue. Memorizing is another way to deal with any possible problems when operating the controls. Visually-impaired users memorize the location of a specific button in a button group, for example a visually-impaired user may identify the second button from the left of a button group as the control for rinse hold function. Users may also use memorization to adjust a knob. The user constructs a relation between the position of the knob, the direction of movement and the value pointed by the knob and memorizes this relation.

Visually-impaired users can not cope with unexpected complications while performing a task. They have to ask for help from a sighted person.

4.5. CONCLUDING REMARKS

There will always be a need for design solutions specific to individuals with disabilities. A typical household product should be designed in such a way that it can be operated by a disabled person; for this study, by a visually-impaired person, independently. For this purpose, problematic points during the interaction between the impaired user and the product should be examined.

First, the term, interaction should be defined clearly. Interaction is a communication that occurs between the user and the machine via the interface. The process of interaction contains steps which repeat themselves until the task is accomplished. The process starts with the perception of information conveyed via the displays on the interface. The following step is the evaluation of the data obtained. Next, motor abilities are used to respond to the machine by changing the positions of controls. After this action, events take place at the machine side. Control elements transfer the data from the human agent to the processing units of the machine and the machine displays a feedback about the result of the task.

Undoubtedly, this communication process might be blocked by several variables. Stepherd (1993; cited in Bridger, 1995) identifies a common problem in control-display integration which he calls “breaking the loop”. In the situation of the disabled user, this problem may be caused by the interface of the product, or by the severe impairment of the user.

After conducting the test to understand interaction between a domestic appliance and a visually-impaired user, problematic points hindering usage of product appropriately are disclosed. First of all, the study reveals that the users do not prefer to purchase appliances with digital displays or membrane push buttons. Having a minimum number of controls is the reason why that product is purchased. Moreover, all users in the study agree with the idea that push buttons would be more usable instead of a rotary selector with many positions.

An unexpected result of the test is about user manuals. All users report about the inadequacy of the user manuals. Some claim that to be able to use the product independently, the manuals are essential. Therefore, one of the significant results of the study is that there is a general lack of user-manuals which would allow visually-impaired users to operate their machine with full-functionality.

4.6. SUGGESTIONS

At the end of the study, the design considerations provided at the previous section is reached. Some of the conclusions drawn from the study were common or related:

Displays

- The visually-impaired user should also have access to important information. Therefore, displays should be multi-sensory: All significant visual information should be conveyed through the auditory and/or tactile senses as well. Visual clues and warnings should be accompanied with a sound warning of a mid-low frequency (Vanderheiden, 1997).

Labels should be large, visible and clear to understand (Lindsey, 1999; Vanderheiden, 1997). Users with low vision need large and visible labels to operate their appliances.

- Tactile markings should be easy to find and feel (Lindsey, 1999).

Controls

- Controls should able to be operated with minimum force, speed and accuracy, taking the needs of the user with the least capacity into consideration (Damon, Stoudt and McFarland, 1966; Lindsey, 1999; Vanderheiden, 1997; Cushman, 1997).

- The number of control elements should be as little as possible for the sake of simplicity (Damon *et al.,* 1966; Vanderheiden, 1997; Cushman, 1997). No complicated or unnecessary actions should be needed to operate the machine (Bridger, 1995). When the user is visually-impaired, less number of elements means easier to perceive the elements and learn their functions.

- Controls should have different forms, shapes, and textures so that they can be distinguished through the senses touch and vision (Damon *et al.,* 1966; Dul and Weerdmeester, 2001). In the case the user who is visually impaired; controls with different forms and textures are a definite requirement to perceive the interface (Vanderheiden, 1997).

- Protruded controls may be preferred to recessed controls. Recessed controls are operated by pushing the button instead of gripping. These kinds of controls may be painful to operate for elderly users (Lindsey, 1999). In addition, in the case the visually-impaired user; protruded controls are more suitable because they can be perceived easily than recessed ones.

- The surfaces of the elements should be non-slippery (Vanderheiden, 1997). Concave buttons and textured knobs should be used to prevent slipping. Knurled

surfaces provide more friction which allows the control element to be gripped easily (Vanderheiden, 1997; Cushman, 1997). Moreover, because of the friction, the visually-impaired user can perceive the motion of the textured knob clearly.

- The space around individual interface elements, their level of protrusion from the interface and the space between the elements should be large enough for fingers of different sizes (Lindsey, 1999). If the user is visually-impaired, the spaces between controls and buttons become more important as it is possible for the user to distinguish the controls and control groups according to the space between specific elements (Vanderheiden, 1997).

- The current position or setting of the controls should be able to be perceived by the visually-impaired users. To attain this goal, the perception of the possible different positions and the current position of the controls should be multi-sensory. Displays which show the current stage of a sequential operation should be addressed to more than a single sense. Absolute reference controls should be preferred over relative controls (Vanderheiden, 1997).

  Discrete selectors and continuous knobs should have tactile marks. Protruded or recessed notches, marks, symbols or letters should be placed both on the surface and on the circumference of the control. Hence the user can infer the position of the selector or continuous knob according to the alignment of these two marks.

  Moreover, a continuous knob should have a tactile mark or symbol indicating which direction it should be turned to increase or decrease the value it is set at.

Manipulation

- When manipulating the parts of an appliance, such as attaching parts to the appliance or opening and closing sections of it, dual latches which must be used at the same time should be avoided (Vanderheiden, 1997).

- Users should be able to attach and detach the accessories without needing extreme accuracy or force (Lindsey, 1999; Vanderheiden, 1997).

Documentation

- Documentation such as manuals and instructions should be accessible by all users, including users with limitations. The documents should be available in different formats such as the digital form, a hardcopy in large print or in Braille. The

documentation should not have sans-serif, small fonts. Basic instructions should also be given on the product, in addition to the documentation (Vanderheiden, 1997).

Upon request, domestic appliances should come with user manuals in Braille, prepared for users with visual impairments. To be more precise, the user manual should instruct in such a way that a non-sighted user can learn how to use the appliance practically. This kind of document will prevent dependence on other people and it allows the visually-impaired user to operate his/her appliance with full-functionality. If the manual also includes the explanations for protruded marks and letters, the user will not have to memorize what actions she must do to perform specific tasks and the location of specific controls on the interface.

Safety

- All warning and alarms should be multi-sensory. Alarms and hazard indicators should not rely only on visual-perception, i.e. a warning should not be consisting of only lights (Vanderheiden, 1997).

  Indicator lights should be supported with auditory displays. To illustrate, for a vacuum cleaner, an indicator light displaying a full dustbag can be accompanied with an auditory signal which goes off for a few seconds when the motor is turned off.

Arrangement of Interface Elements

- Controls and displays which are grouped together because they belong to similar functions, should be distinguished with different methods to prevent the users from mixing them up (Cushman, 1997).

Besides suggestions above, conclusions which are specific to the study and products observed were obtained:

Controls
Rotary Knobs

- A discrete selector with three or four positions should give auditory feedback at each position. The auditory feedback might be a sound that the selector makes. In addition, the direction of rotation for the selector should be given as a haptic feedback. This information can be conveyed via the resistance the selector offers against rotation. At each level, the selector can resist more against further rotation.

- The feedback for a continuous knob can be given by the resistance the knob shows against rotation. To illustrate, the temperature control knob of an iron can show more resistance to further rotation as the value it is set at increases.

- If these discrete selectors provide selection between different tasks, labels for each task should be displayed tactilely. These legends may vary in method from Braille letters to protruded symbols defined in the user manual. If the discrete selector has more than six positions, it becomes difficult to set a value depending only on auditory signals. In any case, displaying positions by raised symbols is a must. If the selector has a large number of possible positions such as over 12, putting distinct marks on each position will be confusing. Instead, placing fewer labels with distinct and raised letters, numbers or symbols at every second position will be more legible.

- However, in cases similar to the program dial of a washing machine, each position refers to a different task. In other words, tasks are not lined in a simple, logical continuity. Therefore, the previous suggestion will not work because an unlabeled position can not be defined with reference to the labels next to it. For this reason, all the positions require labels. In such a situation, symbology might be used and definition of symbols should be given in the user manual. The user might memorize the symbols of tasks she frequently uses, and she can refer to the manual when she wants to use other functions.

Buttons

- In the application of button controls, if more than two identical adjacent buttons are on the interface, tactile marks should be used to identify them.

- If these buttons control the level of an amount or the sequence of a task such as step keys; buttons can be labeled as a group. However, the buttons should also be labeled individually so that the direction of control will be understood.

- Buttons should be latched push buttons so that a visually-impaired user can perceive which button is active.

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APPENDIX A

Table A.1: CHECKLIST FOR OBSERVATION NOTES -WASHING MACHINE

WASHING MACHINE OWNER:
Brand and Model:
Loading and unloading
Opening
Loading
Closing
Other
Errors/ Difficulties
Overall rating for ease of loading and unloading
Users' thoughts; comments, complaints or suggestions
Using the dispenser
Perception of dispenser (easy to find and understand how to operate?)
Usage
Errors/ Difficulties
Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions
Using the Main program dial
Perception of dials (easy to find and understand how to operate?)
Usage
Coping with visual clues/ displays/ labels (success, substituting, modifications...)
Errors/ Difficulties
Other
Overall rating for how easy it is to use

Users' thoughts; comments, complaints or suggestions

Other dials

Perception of dials (easy to find and understand how to operate?)

Usage

Coping with visual clues/ displays/ labels (success, substituting, modifications...)

Errors/ Difficulties

Other

Overall rating for how easy it is to use

Users' thoughts; comments, complaints or suggestions

Push buttons or switches

Perception of buttons/switches (easy to find and understand?)

Usage

Coping with visual clues/ displays/ labels (success, substituting, modifications...)

Errors/ Difficulties

Other

Overall rating for how easy it is to use

Users' thoughts; comments, complaints or suggestions

Program guide

Perception of Program guide

Coping with visual clues/ displays/ labels (success, substituting, modifications...)

Errors/ Difficulties

Overall rating for how easy it is to use

Instructions

Perception of Instructions

Coping with visual clues/ displays/ labels (success, substituting, modifications..)

Errors/ Difficulties

Overall rating for how easy it is to use

Users' thoughts; comments, complaints or suggestions

NOTES:

Table A.2: CHECKLIST FOR OBSERVATION NOTES-VACUUM CLEANER

VACUUM CLEANER OWNER:
Brand And Model:
Transport And Storage
Errors/ Difficulties
Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions
Setting Up
Errors/ Difficulties
Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions
Attaching Brushes and Other Accessories
Perception brushes and Other accessories (easy to find and understand?)
Usage
Coping with visual clues/ displays/ labels (success, substituting, modifications...)
Errors/ Difficulties
Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions
Unwinding And Rewinding The Power Cord
Perception of buttons/switches (easy to find and understand?)
Usage
Coping with visual clues/ displays/ labels (success, substituting, modifications...)
Errors/ Difficulties

Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions
Turning The Vacuum On And Off
Perception of buttons/switches (easy to find and understand?)
Usage
Coping with visual clues/ displays/ labels (success, substituting, modifications..)
Errors/ Difficulties
Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions
Adjusting The Suction
Perception of buttons/switches (easy to find and understand?)
Usage
Coping with visual clues/ displays/ labels (success, substituting, modifications...)
Errors/ Difficulties
Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions
Vacuuming
Usage
Errors/ Difficulties
Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions

NOTES:

Table A.3: CHECKLIST FOR OBSERVATION NOTES-IRON

IRON OWNER:
Brand and Model:
Preparation/ Setting
Setting the ironing board
Plugging the cord
Preparing clothes to be ironed
Errors/ Difficulties
Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions
Filling With Water
Perception of water fill opening (easy to find and understand how to operate?)
Perception of water level
Usage
Coping with visual clues/ displays/ labels (success, Substituting, modifications...)
Errors/ Difficulties
Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions
Temperature Control
Perception of Temperature Control (easy to find and understand how to operate?)
Usage
Coping with visual clues/ displays/ labels (success, Substituting, modifications...)
Errors/ Difficulties
Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions

Handling and Ironing
Perception of Handling (easy to find and understand how to operate?)
Usage of handling/ ironing
Coping with visual clues/ displays/ labels (success, Substituting, modifications...)
Errors/ Difficulties
Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions
Steaming and Spraying
Perception of Steam and spray controls
Perception of Steaming and Spraying actions
Usage of Steam and spray controls
Coping with visual clues/ displays/ labels (success, Substituting, modifications...)
Errors/ Difficulties
Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions
Descaling
Errors/ Difficulties
Other
Overall rating for how easy it is to use
Users' thoughts; comments, complaints or suggestions

NOTES:

APPENDIX B

USER PROFILE AND INTERVIEW QUESTIONS

-Turkish version-

RUMUZ:
AD SOYAD:
ADRES:
CİNSİYET:
YAŞ:
GÖRME DERECESİ:
EĞİTİM DURUMU:
GÖRME ENGELİNE YÖNELİK EĞİTİM:
ELEKTRİKLİ EV EŞYALARINI KULLANMA SIKLIĞI
/Elektrikli Eşyalara, Teknolojik Aletlere Yatkınlık, Yakınlık?
Genel Olarak Elektrikli Aletler:
Çamaşır Makinesi:
Elektrikli Süpürge:
Ütü:

GÖZLEMDEN ÖNCE

Çamaşır Makinesi

- Çamaşır makinenizi siz mi satın aldınız?
- Çamaşır makinenizi ne kadar zamandır kullanıyorsunuz?
- Çamaşır makinenizi alırken özellikle dikkat ettiginiz (aradığınız) özellikler var mıydı? Varsa neler?

- Çamaşır makinenizi değiştirmeyi düşünüyor musunuz? Neden?

Elektrikli Süpürge

- Elektrikli süpürgenizi siz mi satın aldınız?
- Elektrikli süpürgenizi ne kadar zamandır kullanıyorsunuz?
- Elektrikli süpürgenizi alırken özellikle dikkat ettiginiz (aradığınız) özellikler var mıydı? Varsa neler?

- Elektrikli süpürgenizi değiştirmeyi düşünüyor musunuz? Neden?

Ütü

- Ütünüzü siz mi satın aldınız?
- Ütünüzü ne kadar zamandır kullanıyorsunuz?
- Ütünüzü alırken özellikle dikkat ettiginiz (aradığınız) özellikler var mıydı? Varsa neler?

- Ütünüzü değiştirmeyi düşünüyor musunuz? Neden?

GÖZLEMDEN SONRA

Çamaşır makinesi için;

- Cihazınızın en çok begendiğiniz işinizi/kullanmanızı kolaylaştıran özelliği nedir? (Ürüne has bir özellik? Dügmeler? vs.)

- Cihazınızdaki düğmeler, göstergeler vb. elemanlar arasında cihazınızı kullanmanızı zorlaştıran, ya da engel olanlar var mı? Hangileri? Neden?

- Cihazınızda neleri değiştirmek isterdiniz? (fonksiyon olarak değil de, biçim olarak..)

Ya da... (Cihazınızın tasarımında biçimsel olarak değiştirmek istediğiniz yönler var mı?

- Sizce bir görme engelli kullanıcının hatasız ve iyi bir performansla kullanabilmesi için bir çamaşır makinesi tasarımında nelere dikkat edilmelidir?

Elektrikli süpürge için;

- Cihazınızın en çok begendiginiz işinizi/kullanmanızı kolaylaştıran özelliği nedir? (o ürüne has bir özellik? Dügmeler?..vs.)

- Cihazınızdaki dügmeler, göztergeler vb. elemanlar arasında cihazınızı kullanmanızı zorlaştıran, ya da engel olanlar var mı? Hangileri? Neden?

- Cihazınızda neleri değiştirmek isterdiniz? (fonksiyon olarak değil de, biçim olarak..)

Ya da... (Cihazınızın tasarımında biçimsel olarak değiştirmek istediğiniz yönler var mı?

- Sizce bir görme engelli kullanıcının hatasız ve iyi bir performansla kullanabilmesi için bir elektrikli süpürge tasarımında nelere dikkat edilmelidir?

Ütü için;

- Cihazınızın en çok begendiginiz işinizi/kullanmanızı kolaylaştıran özelliği nedir? (o ürüne has bir özellik? Dügmeler?..vs.)

- Cihazınızdaki dügmeler, göztergeler vb. elemanlar arasında cihazınızı kullanmanızı zorlaştıran, ya da engel olanlar var mı? Hangileri? Neden?

- Cihazınızda neleri değiştirmek isterdiniz? (fonksiyon olarak değil de, biçim olarak..)

Ya da... (Cihazınızın tasarımında biçimsel olarak değiştirmek istediğiniz yönler var mı?

- Sizce bir görme engelli kullanıcının hatasız ve iyi bir performansla kullanabilmesi için bir ütü tasarımında nelere dikkat edilmelidir?

NOTLAR:

APPENDIX C

Table C.1: INTERFACE ANALYSES FOR WASHING MACHINES

USER A Beko 2600

To operate:

1. Adding the detergent and the fabric softener.
2. Setting the washing program.
3. Setting the water temperature. (starts)
4. (optional) Pressing water saving button.

1. **Washing program:** protruded single rotation (CW) selector.

2. **Water temperature:** protruded multi-rotation selector.

Selectors are identical in terms of form. Yet, they distinguish with the scale marking and rotation.

3. **Water saving option:** latching push button.

Button distinguishes from the ground with its texture and visual label on it.

4. **Power indicator light:** between water temperature selector and water saving option.

5. **Table of instructions** regarding program selection above the control panel.

Modification: none

Length of ownership: 16 years.

USER B Arçelik 3650Y

To operate:

1. Adding the detergent and the fabric softener.
2. Setting the washing program.
3. Setting the water temperature.
4. Pressing the power button. (starts)
5. (optional) Choosing one or more washing options.

1. **Washing program:** protruded single rotation (CW) selector with textured side faces for easy gripping.

2. **Water temperature:** protruded multi-rotation selector with textured side faces for easy gripping.

Selectors are identical in terms of form. Yet, they distinguish with the scale marking and rotation. They have a display system surrounding the knob and rotating together it.

3. **Power button:** alternate push button at the left of the button group.

4. **Washing options:** each button is supported with a function light that points out active task. Above each button, it is placed a label to identify the control.

5. **Door unlock:** alternate push button between two selectors.

Modification: notches around the selectors of water temperature and washing program.

Length of ownership: 5 years.

Table C.1: INTERFACE ANALYSES FOR WASHING MACHINES

USER C Ariston AVL85

To operate:

1. Pressing the power button.
2. Setting the washing program.
3. Setting the water temperature.
4. Setting the spinning velocity
5. Adding the detergent and the fabric softener.
6. Pressing the start/restart button. (starts)
7. (optional) Choosing one or more washing options

1. **Washing program:** single rotation (CW) selector.

Bigger than the others and it has its labels around it on a raised surface. Its display system surrounds the knob and rotates together it.

2. **Water temperature:** protruded multi-rotation selector.

3. **Spinning velocity:** protruded multi-rotation selector.

Water temperature and spinning velocity selectors are identical in terms of design. They have labels on their side face. They can be recessed by pushing.

4. **Washing options:** the group of four alternate push buttons with their back lights.

5. **Door locked indicator light** between water program selector and power on button.

6. **Operating mode lights** show the stages of the washing. They have static displays at the right side inform about the remaining time of the task.

Modification: none

Length of ownership: 2 years.

USER E Profilo Pasific 5208

To operate:

1. Adding the detergent and the fabric softener.
2. Setting the washing program.
3. Setting the water temperature.
4. Pressing the power button. (starts)
5. (optional) Pressing the rinse hold button.

1. **Washing program:** single rotation (CW) selector.

2. **Water temperature:** multi-rotation selector.

Selectors are identical in terms of form. Yet, they distinguish with the scale marking and rotation. Both selectors have bars on them and notches on those bars.

3. **Power button:** latching push button at the right of the selectors with a power indicator light above it.

4. **Rinse hold option:** latching push button.

Modification: none

Length of ownership: more than 10 years.

Table C.1: INTERFACE ANALYSES FOR WASHING MACHINES

USER D Beko 2418 BX

To operate:

1. Setting the washing program.
2. Setting the water temperature.
3. Setting the spinning velocity
4. Adding the detergent and the fabric softener.
5. Pressing the start/restart button. (starts)
6. (optional) Choosing one or more washing options.

1. **Washing program:** protruded single rotation (CW) selector with textured side faces for easy gripping.

2. **Water temperature:** protruded multi-rotation selector with textured side faces for easy gripping. These selectors are identical in terms of form. Yet, they distinguish with the scale marking and rotation. They have a display system surrounding the knob and rotating together it. Selectors can be recessed by pushing.

3. **Spinning velocity:** protruded multi-rotation selector with a scale marking on the circumference and a stripe over the knob, on the initial position.

4. **Power button:** latching push button at the left of the group of the optional buttons.

5. **Washing options:** latching push buttons with their labels above them.

6. **Table of instructions** regarding program selection on the detergent dispenser.

Modification: none

Length of ownership: 3 years.

USER J Beko 2518 C

To operate:

1. Setting the washing program.
2. Setting the water temperature.
3. Adding the detergent and fabric softener.
4. Pressing the start/restart button. (starts)
5. (optional) Choosing one or more washing options.

1. **Washing program:** protruded single rotation (CW) selector with textured side faces for easy gripping.

2. **Water temperature:** protruded multi-rotation selector with textured side faces for easy gripping. These selectors are identical in terms of form. Yet, they distinguish with the scale marking and rotation. They have a display system surrounding the knob and rotating together it. Selectors can be recessed by pushing.

3. **Power Button:** latching push button at the left of the group of the optional buttons.

4. **Washing Options:** latching Push buttons with their labels above them.

5. **Door Unlock:** alternate push button between two selectors.

Modification: none

Length of ownership: 3 years.

Table C.1: INTERFACE ANALYSES FOR WASHING MACHINES

USERS F and I Arçelik 2100

To operate:

1. Adding the detergent and the fabric softener.
2. Setting the washing program.
3. Setting the water temperature.

(starts)

4. (optional) Pressing the water saving or the electricity saving buttons.

5. **Washing program:** single rotation (CW) selector.

6. **Water temperature:** multi-rotation selector.

Selectors are identical in terms of form. Yet, they distinguish with the scale marking and rotation. Both selectors have bars on them and notches on those bars.

They have a display system surrounding the knob and rotating together it.

7. **Water and electricity saving options:** latching push buttons.

Button distinguishes from the ground with its texture and visual label on it.

8. **Power indicator light** between water temperature selector and water saving option.

Modification: none

Length of ownership: User F: 16 years – User I: 20 years.

USER G Arçelik 3300

To operate:

1. Adding the detergent and the fabric softener.
2. Setting the washing program.
3. Setting the water temperature.
4. Pressing the power button.

(starts)

5. (optional) Pressing the water saving or the rinse hold buttons.

1. **Washing program:** single rotation (CW) selector.

2. **Water temperature:** multi-rotation selector.

Selectors are identical in terms of form. Yet, they distinguish with the scale marking and rotation. Both selectors have bars on them and raised stripes on those bars.

3. **Power button:** latching push button with a label on it and recessed surface for fingers.

4. **Rinse hold option:** latching push b1utton with a label on it and convex circles for fingers.

5. **Water saving option:** latching push button with a label on it and recessed surface for fingers.

Button distinguishes from the ground with its texture and visual label on it.

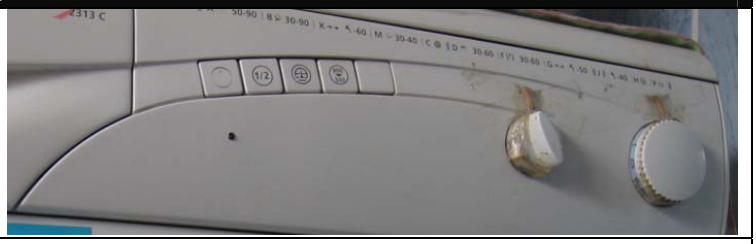
6. **Table of instructions** regarding program selection above the control panel.

Modification: none

Length of ownership: 10 years.

Table C.1: INTERFACE ANALYSES FOR WASHING MACHINES

USER H Beko 2313 C



To operate:

1. Adding the detergent and the fabric softener.
2. Setting the washing program.
3. Setting the water temperature.
4. Pressing the power button. (starts)
5. (optional) Choosing one or more washing options.

1. **Washing program:** protruded single rotation (CW) selector. It can be recessed by pushing.

2. **Water temperature:** protruded multi-rotation selector with its bar on it.

Selectors have scale markings on their side face.

3. **Power button:** alternate push button at the left of the group of the optional buttons.

4. **Washing options:** the group of three alternate push buttons with their labels on them.

5. **Power indicator light:** below the power button.

Modification: Program selector has two toothpicks. One of them is fixed on the initial position of the selector. The other toothpick is on the side face of the selector, over the “Program E”.
Water temperature selector has three toothpicks. Two of them are fixed on the side face of the selector, over the temperature values. The other toothpick is on the initial point of the bar.
Length of ownership: 8 years.

Table C.2: OBSERVATION FINDINGS FOR WASHING MACHINES

STEPS OF THE TASK	USER A *Beko 2600*	USER B *Arçelik 3650Y*	USER C *Ariston AVL85*	USER D *Beko 2418 BX*	USER E *Profilo Pasific 5208*
					
Loading and Unloading	Understands whether the washer is full or not by touching the laundry in the tank. *No significant error or difficulty.*	Pushes harder the door for a few times. *No significant error or difficulty.*	Understands whether the washer is full or not by touching the laundry in the tank. Hesitates whether the door is closed and pushes to ensure.	Not Observed	Not Observed
Using the Dispenser	Hesitates which dispenser is for detergent or fabric softener and controls with fingers.	Uses a scale cup for detergent. Controls the detergent level with fingers.	Finds where the detergent case is with reference to the buttons. Adds a handful of detergent into the case.	Not Observed	Grips and opens easily. Keeps left forefinger in the case to perceive the level of the detergent.
Using the Program Selector	Counts the number of clicks to set the Program F. The task can not be accomplished and she asked for help.	Uses a notch on the program selector made by her. *Knows:* *Short program when the notch on the selector is parallel with the mark on the program display.*	Uses a notch on the initial point of the selector. First, sets the notch at vertical position that is the initial position of selector. Then, counts the positions and stops at 7th pos.	Can not use the program selector without help. Plans to affix a match stick to mark the starting point on the knob and display around it.	Places the bar on the selector on a vertical position. *Knows:* *The vertical position of the bar corresponds to the Program A.*
Using Other Knobs (Temperature and Spinning)	Adjusts the temperature to 45° C by setting the position of the bar somewhere between vertical and horizontal. *Knows:* *Water temperature is 30° C when the bar on the selector is horizontal.* *Water is 60° C in vertical position of the bar.*	Uses three distinct marks on the 30° C, 60° C and 90° C and a notch on the knob. Uses both hands to understand whether the notch on the selector and mark on the display are aligned.	Sets the temperature to 40° C by rotating clockwise and stopped at the second position. Spin velocity is set to 750 rpm.	1. Gets the knob to its initial point. 2. Adjusts the temperature by turning the selector CW and by counting the positions and click sounds.	Places the bar on the selector on a vertical position. *Knows:* *The horizontal position of the selector bar corresponded to the value of 30° C and vertical position means 60°C.*
Push Buttons or Switches	Not Observed.	Pushes the first button from left, among four identical buttons. Use of other buttons not observed.	Selects one of the washing options, easy ironing.	Runs the washing machine pressing on/off button. Use of other buttons not observed.	Runs the washing machine pressing on/off button. Sound made by the working machine is the feedback.
Program Guide	Not Observed.	Not Observed.	Not Observed.	Not Observed.	Not Observed.
Instructions	Not Observed.	Not Observed.	Not Observed.	Not Observed.	Not Observed.
Other	-	-	-	-	-

Table C.2: OBSERVATION FINDINGS FOR WASHING MACHINES

STEPS OF THE TASK	USER F *Arçelik 2100*	USER G *Arçelik 3300*	USER H *Beko 2313 C*	USER I *Arçelik 2100*	USER J *Beko 2518 C*
					
Loading and Unloading	Not Observed	Understands whether the washer is full or not by touching the laundry in the tank. *No significant error or difficulty.*	Understands the door is unlocked when heard the sound from the machine. Opens the door by pushing and checks out the load washer.	Uses both hands to open and close the door.	Not Observed
Using the Dispenser	No problem about gripping but has to pull a bit hard the detergent case. Controls the detergent level with fingers.	Controls if the detergent is present in dispenser. Controls the detergent level with fingers.	Not Observed	Uses both hands to open and close the dispenser.	Not Observed
Using the Program Selector	Accomplishes the step with getting help. After understanding that the status of the selector was Program D, can turn the selector to the Program F.	Uses without problem du to the marks on the bar of the selectors. *Knows:* *When the bar is vertical, washing program is set to Program A.* Infers that at the 6 o'clock position, the program is set to D.	Uses two distinct sticks attached around the rotary knob and a mark above the knob. *Knows:* *Two distinct sticks corresponds the Programs A and D.* Selects Program D by aligning the short stick on the selector and stick on the mark.	Asks for help since she does not know which position of the rotary knob corresponds to which program.	Raises the program selector by pushing. Reads the letter "D" on the program display, and then rotates the knob CW until it points at Program A.
Using Other Knobs (Temperature and Spinning)	Asks for help about the present position of the selector. Then, turns the selector approximately, between the values 30°C and 40°C.	Sets the selector to the 3 o'clock position that is 30° C. *Knows:* *12 o'clock direction means that the temperature is off; 6 o'clock refers to 60°C.*	Uses two sticks on the rotary knob and around the rotary knob. *Knows:* *Two sticks aligned refers to the value of 40° C.*	Finds the water temperature selector by moving fingers of both hands over the control panel. a	Turns the selector CCW until it can not rotate further. Then, rotates CW and counts the positions by heart starting from 30° C.
Push Buttons or Switches	Runs the washing machine pressing on/off button lightly. Use of other buttons not observed.	Perceives tactilely three push buttons at the center of the control panel. Pushed the button on the left which is on/off button. Use of other buttons not observed.	Runs the washing machine pressing on/off button. Looks for the correct one among five identical buttons by moving her fingers over the control panel. *Memorized place of the buttons.*	Finds two washing options buttons by moving the fingers of two hands over the panel. Use of these buttons not observed.	Runs the washing machine pressing on/off button where buttons is at the left side of the group of four push.
Program Guide	Not Observed.	Not Observed.	Not Observed.	Not Observed.	Not Observed.
Instructions	Not Observed.	Not Observed.	Not Observed.	Not Observed.	Not Observed.
Other	Faces difficulty in plugging and spends some time.	-	-	-	-

Table C.3: INTERVIEW FINDINGS FOR WASHING MACHINES

QUESTIONS	USER A Beko 2600	USER B Arçelik 3650Y	USER C Ariston AVL85	USER D Beko 2418 BX	USER E Profilo Pasific 5208	USER F Arçelik 2100	USER G Arçelik 3300	USER H Beko 2313 C	USER I Arçelik 2100	USER J Beko 2518 C
Which interface components or features are useful to you or make the appliance easier to use?	Water temperature selector is easy to use.	None.	Selectors and push buttons are easy to use.	Presence of the delicate washing function.	Relative ease of operation (the appliance was bought when the user had sight)	None.	Program and temperature selectors have raised marks.	Selectors and push buttons are protruded on the control panel.	None.	Large and clear labels on program and temperature selectors.
Which interface components or features make the appliance more difficult to use?	Cannot set temperature precisely. Control panel lacks auditory and tactile clues. More than one function is activated with a single button or selector.	Program and temperature selectors lack auditory and tactile clues. Selectors have to be manually marked.	Unable to utilize all the functions of the appliance because of the lack of a user manual in Braille.	Program selector lacks auditory and tactile clues.	Cannot set temperature precisely.	Selectors lack auditory and tactile clues.	None.	None.	Program and temperature selectors lack auditory and tactile clues.	Push buttons lack explicit labels.
For a visually-impaired user to be able to use a washing machine adequately, which changes should be made in the design of the washing machine?	After finishing a washing program, the position of the program selector should be clear. Each task should be assigned to a unique knob or button	Push buttons should be used for most of the functions. Appliance might give spoken feedback on program selection. Buttons and selectors should be labeled in Braille or regular, raised letters.	Buttons and knobs should be more salient and distinctive. A full manual in Braille alphabet might be included in the appliance.	Selectors might be marked with tactile clues to indicate their current position.	Appliance might give spoken feedback about controls and displays. Buttons and selectors should generate auditory feedback at each position and should be labeled in Braille or regular, raised letters.	Buttons and selectors should be labeled in Braille or regular, raised letters. Buttons and selectors should generate auditory feedback at each position. Latching push buttons should be preferred.	Buttons and selectors should be labeled in Braille or regular, raised letters.	Buttons and selectors should be labeled in Braille or regular, raised letters.	Buttons and selectors should be labeled in Braille or regular, raised letters. Appliance might give spoken feedback about controls and displays.	Large and clearly visible rotary selectors should be preferred. Buttons and selectors should be labeled in Braille or regular, raised letters.

APPENDIX D

Table D.1: INTERFACE ANALYSES FOR VACUUM CLEANERS

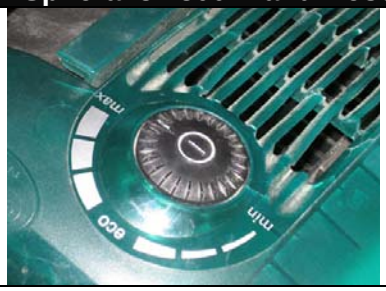
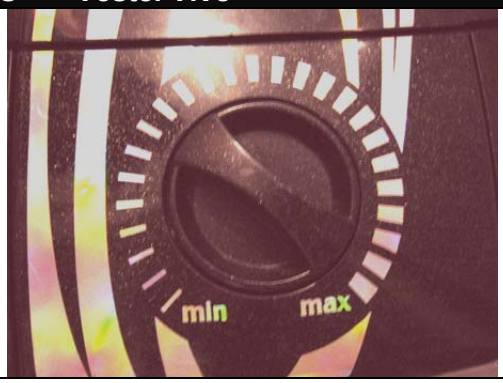
USER A and B Bosch Sphera28 1800W and Bosch Sphera21 1400W	
	
To operate: 1. Pulling the power cord and plugging. 2. Pressing the power button. 3. Setting the suction power.	
• **Single switch with two functions:** **Turning on/off** as the alternate push button. **Adjusting the suction power** as the rotary selector. Texture on the switch for easy gripping. • **Rewinding the power cable:** no button for rewinding. Pulling a bit and release gets the cable rewind. • **Protruded instruction** above the cable entrance depicting how to use is. • **Static displays** around the knob indicating the amount of suction. • **Graphic symbol** on the button identifying the power button. **Modification:** none **Length of ownership:** User A: 10 months - User B: 5 years.	
USER D Sphera20 1300W	
	
To operate: 1. Pulling the power cord and plugging. 2. Pressing the power button.	
• **Turning on/off** the alternate push button. • **Rewinding the power cable:** no button for rewinding. s Pulling a bit and release gets the cable rewind. • **Protruded instruction** above the cable entrance depicting how to use is. • **Static displays** around the knob indicating the amount of suction. • **Graphic symbol** on the button identifying the power button. **Modification:** none **Length of ownership:** 1 year.	

Table D.1: INTERFACE ANALYSES FOR VACUUM CLEANERS

USER C Vestel Vivo



To operate:

4. Pulling the power cord and plugging.
5. Pressing the power button.
6. Setting the suction power.

- **Turning on/off**: alternate foot push button with a label on it.
- **Rewinding the power cable:** momentary foot push button with a label on it.
- **Adjusting the suction power:** rotary knob with a bar for easy gripping
- **Static display:** around the knob indicating the amount of suction**.**

Modification: none

Length of ownership: 2 years.

USER E Sphera20 1300W

To operate:

3. Unwinding power cord and plugging.
4. Pressing the power button.
5. Choosing one of two suction power levels.

Two identical rocker switches:

- **Turning on/off**: two position rocker switch with a label next to it.
- **Adjusting the suction power**: two position rocker switch with a label next to it.
- **Rewinding the power cable:** no rewinding mechanism.
- **Two clips:** attaching the water tank to the main body of the vacuum cleaner.

Modification: none

Length of ownership: 1 year.

Table D.1: INTERFACE ANALYSES FOR VACUUM CLEANERS

USER F Ihlas tr

To operate:

7. Filling the water compartment.
8. Unwinding power cord and plugging.
9. Pressing the power button.
10. Choosing the vacuuming method: dry or wet.

Two identical rocker switches:

- **Turning on/off**: two position rocker switch with a label next to it.
- **Adjusting the suction power:** two position rocker switch with a label next to it.
- **Rewinding the power cable:** no rewinding mechanism.
- **Rocker switch** on the handle of sucker wand to turn on/off smaller.
- **Two clips:** attaching the water tank to the main body of the vacuum cleaner.

Modification: none

Length of ownership: 10 years.

USER G Rowenta Quadron

To operate:

6. Unwinding power cord and plugging.
7. Choosing the cleaning method: dry or wet.

Two Alternate Push Buttons

- **Turning on/off**: alternate push button with label on it.
- **Washing Mode**: alternate push button with label on it.

Raised stripes on both buttons to avoid fingers slipping.

- **Rewinding the power cable:** no rewinding mechanism.
- **Two clips:** attaching the water tank to the main body of the vacuum cleaner.

Modification: none

Length of ownership: 6 years

Table D.1: INTERFACE ANALYSES FOR VACUUM CLEANERS

USER H Simtel Super

To operate:

11. Unwinding power cord and plugging.
12. Pressing the power button.
13. Opening the cover on the top of the vacuum cleaner.

- **Turning on/off**: two position rocker switch with a symbol “0”.
- **Rewinding the power cable:** no rewinding mechanism.
- **Latch:** opening the cover on the vacuum cleaner.

Modification: none

Length of ownership: 12 years**.**

USER I Arçelik Super Electronic

To operate:

8. Pulling the power cord and plugging.
9. Pressing the power button.
10. Setting the suction power.

- **Turning on/off**: alternate foot push button with a label on it.
- **Rewinding the power cable:** momentary foot push button with a label on it.

Foot buttons have tactile texture for easy gripping.

- **Adjusting the suction power:** three latching push buttons for three level of suction.
- **Dynamic display consisting a group of lights with a static display** showing the level of suction over the suction adjustment buttons
- **Hazard light with a static display** warning about full dust bag.

Modification: none

Length of ownership: 12 years

Table D.1: INTERFACE ANALYSES FOR VACUUM CLEANERS

USER J Simtel Super	
	 
To operate: 1. Pulling the power cord and plugging. 2. Pressing the power button.	
• **Turning on/off**: alternate foot push button with a raised symbol on it. • **Rewinding the power cable:**: momentary foot push button with a raised symbol on it. Buttons have texture consisting raised stripes for easy gripping. • **Handle that can be folded.** **Modification:** None **Length of ownership:** not owner. Uses for temporarily.	

Table D.2: OBSERVATION FINDINGS FOR VACUUM CLEANERS

STEPS OF THE TASK	USER A *Bosch Sphera*	USER B *Bosch Sphera*	USER C *Vestel Vivo*	USER D *Bosch Sphera*	USER E *Fantom Master*
					
Transport	Dust compartment lid is released. Spends minutes to fix.	Carries easily.	Carries easily.	Carries easily.	Faces difficulty in transporting. Asks for help from daughter.
Setting Up	Already set up.	Already set up.	Already set up.	Already set up.	Already set up.
Unwinding and Rewinding the Power Cord	Unwinds the power cord without problem. Hesitates in winding the power cord.	Unwinding mechanism is broken down. Power cord is already unwound.	Power cord is already unwound. Controls whether the power cable is stuck under the vacuum cleaner.	Pulls the power cord about ten times, until reaching desired length.	No rewinding mechanism. Unwinds the power cord without problem.
Turning the Vacuum on and Off	1. Uses both hands to perceive the surface of the vacuum cleaner. 2. Uses both hands to push to find the power button.	1. Finds the power button after moving her right hand over the surface of the cleaner in a short time. 2. Pushes the button with her thumb.	1. Perceives the power button with her palm at first attempt. 2. Pushes the button a bit hard. 3. Not confuse about the place of the button. 4. Finds the power button with reference to the part she touched.	1. Understands the place and the position of the vacuum cleaner. 2. Searches the power button by moving her hand over the device. 3. Pushes the button with left palm strongly.	1. Holds the handle on top. 2. Pulls it to the left and turning it so that hose socket faces to the front. 3. Pushes the switch which is closer at first attempt.
Adjusting the Suction	Adjusts the suction by rotating the selector which is actually the same control element with the power button. Makes effort adjusting the selector because she can not grip the selector completely.	Not Observed. Vacuums at the same suction level. *Knows:* *Turning the selector left decreases the suction and vice versa.*	Not Observed. *Knows:* *CW direction of the knob increases the suction.*	Not Observed. (Vacuum cleaner has one suction level.)	1. Keeps her left thumb on the handle. 2. Moves her index finger between the switches.
Vacuuming	Vacuums moving the brush back and forth. Vacuums the carpet bending to check the surface of the carpet vacuumed.	Vacuums the carpet without bending.	Uses the handle on the sucker wand to direct the brush. Vacuums moving the brush back and forth. Vacuums the floor without bending.	Uses both hands to direct the suction wand. Vacuums the carpet standing straight with a continuous and linear motion.	Uses both hands to direct the suction wand. Vacuums moving the brush back and forth. Vacuums the carpet bending slightly.

Table D.2: OBSERVATION FINDINGS FOR VACUUM CLEANERS

STEPS OF THE TASK	USER F *Ihlas Tr*	USER G *Rowenta Quadron*	USER H *Simtel Super*	USER I *Arçelik Super Electronic*	USER J *Arçelik S 6550*
					
Transport	Faces difficulty in transporting: 1. Carries the body of the vacuum cleaner. 2. Brings the hoses, brush and hose for washing.	Not observed.	Faces difficulty in transporting.	Not Observed.	Carries easily.
Setting Up	Spends two minutes to attach the parts together: 1. Fills the vacuum cleaner's tank with water. 2. Faces no difficulty in placing the tank but, 3. Faces difficulty in fixing the clips to the water tank. 4. Inserts the hose into the suction socket.	Already set up.	Already set up.	Unfolds the hose.	Faces no difficulty in attaching hose and suction wand. Setting the thumb latch on the brush to floor vacuuming.
Unwinding and Rewinding the Power Cord	No rewinding mechanism. Power cord is already unwound.	No rewinding mechanism. Unwinds the power cord without problem.	No rewinding mechanism. Unwinds the power cord without problem.	Power cord is already unwound. Rewinds the power cord with foot push button.	Pulls the power cord and in the meantime, Pushes the machine down with foot to pull the power cable easily.
Turning the Vacuum on and Off	Presses the power button with her thumb when holding the handle.	Two buttons identical in form on top of the cleaner. Not hesitate about which one is the power button.	1. Carries the vacuum cleaner one step behind with two hands. 2. Failure in first attempt to turn on the switch. (because of the opened cover hides the switch)	1. Finds the control panel at first attempt. 2. Touches somewhere middle and left side of the panel. 3. Moves fingers to the right side of the vacuum cleaner. 4. Pushes the large foot button by two fingers.	1. Pushes the wrong button, cable unwinding one. 2. Pushes it one more time because of receiving no feedback. 3. Understands that is the wrong button and pushes the other button instantly.
Adjusting the Suction	Not Observed.	Not Observed.	Not Observed. (Vacuum cleaner has one suction level.)	Shows which button correspond with which level of suction. Understands the suction level due to the engine noise.	Not Observed. (Vacuum cleaner has one suction level.)
Vacuuming	Uses the handle on the sucker wand to direct the brush. Vacuums moving the brush back and forth. Face no difficulty until stuck the cable under the brush.	Vacuums by managing the wand with both hands in circular movements.	Vacuums the rug bending. Uses the right hand to unfold the rug using hands to understand whether the floor is cleaned.	Vacuums by managing the wand with both hands. Vacuums moving the brush back and forth.	Uses the sucking wand without brush to clean the corners.

Table D.3: INTERVIEW FINDINGS FOR VACUUM CLEANERS

QUESTIONS	USER A Bosch Sphera	USER B Bosch Sphera	USER C Vestel Vivo	USER D Bosch Sphera	USER E Fantom Master	USER F Ihlas Tr	USER G Rowenta Quadron	USER H Simtel Super	USER I Arçelik Super Electronic	USER J Arçelik S 6550
Which interface components or features are useful to you or make the appliance easier to use?	Automatic cable rewind.	Generally satisfied with the performance.	Generally satisfied with the performance.	Light weight of the device. Simplicity of operation.	Large and easy to find buttons.	Easy to find power on/off button.	High cleaning performance.	High suction power. Easy to find suction power adjustment button.	Generally satisfied with the performance.	Simplicity of operation. Presence of few buttons.
Which interface components or features make the appliance more difficult to use?	Parts of the device can break apart easily.	Lack of an auditory feedback that alerts when the dust bag is full.	None.	Lack of a sofa cleaning function.	None.	None.	Parts of the appliance do not fit properly.	Very noisy motor	None.	Lack of a suction power adjustment selector
For a visually-impaired user to be able to use a vacuum cleaner adequately, which changes should be made in the design of the vacuum cleaner?	Parts of the appliance should be made easy to attach.	Appliance should be light.	Appliance should be operated with a single switch.	Raised letters might be placed on the suction power adjustment buttons.	Generally satisfied with the performance of current vacuum cleaner.	A full manual in Braille alphabet might be included in the appliance.	A feature or apparatus might be added to check if the area vacuumed is properly cleaned.	Non-plastic brushes as plastic brushes tend to break if they strike objects during cleaning.	Appliance might give spoken feedback about controls and displays.	Durable plastic brushes might be included for cleaning corners instead of metal. The hose should be designed so that it would not fold easily. Dust bag replacement should be made easier.

APPENDIX E

Table E.1: INTERFACE ANALYSES FOR IRONS

USER A Philips Azur Cassetta 50



- **Adjusting temperature:** multi-rotation rotary knob on the water tank under the handle.

Static display consisting of symbols representing different temperature ranges and raised dot around it, on the initial point.

- **Adjusting steam power:** detent thumbwheel with three positions over the handle near where the thumb is held. Extra part with a different color identifying the initial position of the selector.

Texture around for easy gripping.

- **Steaming and spraying:** identical alternate push buttons positioned close to where thumb will stand.
- **Power Light** aligned with steam selector and push buttons on the handle.
- **Water Tank:** transparent and removable.

Modification: none

Length of ownership: 10 years.

USER B Braun Optistyle


- **Adjusting temperature:** multi-rotation rotary knob on the water tank under the handle.

Static display consisting of symbols representing different temperature ranges.

Raised mark of triangle on the water tank next to the knob to identify the position of the knob**.**

Texture around for easy gripping.

- **Adjusting steam power:** rotary knob placed on the nose of the iron.

Texture around for easy gripping and raised stripe around the knob to identify the position of the knob**.**

The control functions as an anti-calc valve used for anti-calc system when it is turned CCW with respect to the symbol and the stripe on the circumference being aligned.

Symbology on the knob.

- **Steaming and spraying:** identical alternate push buttons positioned close to where thumb will stand. Steaming button indicated with a red dot, spraying button with a blue dot.
- **Indicator light** aligned with steam selector and push buttons on the handle.
- **Water tank:** transparent.

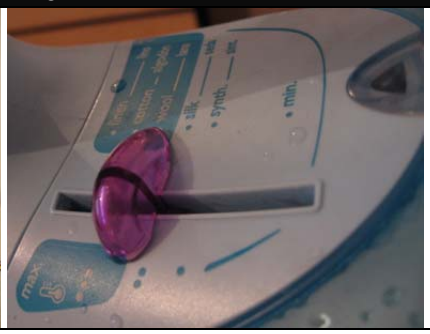
Cover on the water fill opening.

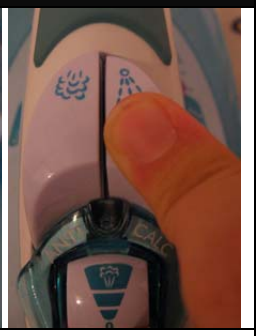
Modification: none

Length of ownership: 5 years.

Table E.1: INTERFACE ANALYSES FOR IRONS

USER C Tefal Aquaspeed 120





- **Adjusting temperature:** continuous sliding switch on the water tank under the handle.

Static display consisting of symbols representing different temperature ranges.
Multi-position rocker switch that is used for swapping between the spraying or steaming.

- **Activating function of steaming** by moving the switch to up.
- **Activating function of spraying** by moving the switch to down.

Keeping the switch in the middle of two positions turns off both actions.

- **Steaming and spraying:** two identical alternate push buttons beyond the rocker switch.

They are distinguished by visual static displays on them.

- **Water tank:** transparent.

Cover on the water fill opening.
Modification: none
Length of ownership: 2 years.

USER G Tefal Supergliss 10


- **Adjusting temperature:** multi-rotation rotary knob over the water tank under the handle.

Static display consisting of symbols representing different temperature ranges.
Raised stripe on the water tank next to the knob to identify the position of the knob**.**
Texture around for easy gripping.
Multi-position rocker switch that is used for swapping between the spraying or steaming.

- **Activating function of steaming:** by moving the switch to up.
- **Activating function of spraying:** by moving the switch to down.

Keeping the switch in the middle of two positions turns off both actions.

- **Spraying:** alternate push button behind the rocker switch.

Tactile static display on it.

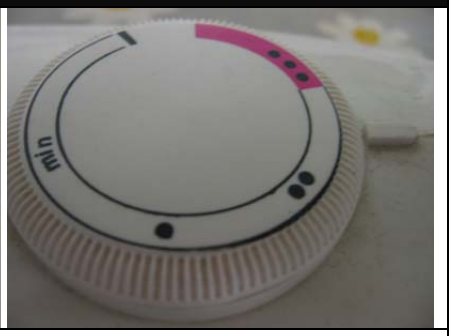
- **Water tank:** transparent.

Cover On The Water Fill Opening
Modification: none
Length of ownership: 10 years.

Table E.1: INTERFACE ANALYSES FOR IRONS

USER D Rowenta Trio Inox





- **Adjusting temperature:** multi-rotation rotary knob over the water tank under the handle.

Static display consisting of symbols representing different temperature ranges.
Raised stripe n the water tank next to the knob to identify the position of the knob**.**
Texture around for easy gripping.

- **Adjusting spraying:** multi-rotation continuous knob over the handle near where the thumb is held.

Texture around for easy gripping.
A tactile stripe over the knob and static display around it consisting symbols identifying rotation of the knob.

- **Spraying:** alternate push button positioned on the nose of the iron.

Tactile symbol over the button.

- **Power light** on the side of the iron.
- **Water tank:** transparent window on the side of the body.
- **Water fill opening:** hidden and can be reached by removing the front part of the iron.

Modification: none
Length of ownership: 3 years.

USER I Rowenta

- **Adjusting temperature:** multi-rotation rotary knob over the water tank under the handle.

Static display consisting of symbols representing different temperature ranges.
Raised stripe n the water tank next to the knob to identify the position of the knob**.**
Texture around for easy gripping.

- **Spraying:** alternate push button positioned on the nose of the iron.
- **Power light** on the handle of the iron.
- **Water tank:** transparent stripe on the tank with static display to show the level of water in the tank.

Modification: none
Length of ownership: 15 years.

Table E.1: INTERFACE ANALYSES FOR IRONS

USER E and F ***Rowenta Professional (1300 W, 2000 W)***



Rowenta Professional 1300 W (User E)

- **Adjusting temperature:** multi-rotation rotary knob on the water tank under the handle.

Static display consisting of symbols representing different temperature ranges.
Raised mark on the water tank next to the knob to identify the position of the knob**.**
Texture around for easy gripping.

- **Activating function of steaming:** two-position slider switch turning on/off the steam.
- **Steaming:** alternate push button with tactile symbol on it. (for Professional 2000 W)

Alternate push button with a blue round on it. (for Professional 1300 W)

- **Spraying:** alternate push button with tactile symbol and with texture to ease gripping.
- **Power light** aligned with steaming and spraying buttons.
- **Water tank:** transparent (for Rowenta Professional 2000 W); transparent stripe on the tank (for Rowenta Professional 1300 W)

Modification: none
Length of ownership: User E: 1 year; User F: 1 year.

Rowenta Professional 2000 W (User F)

USER H ***Teknur***


- **Adjusting temperature:** multi-rotation rotary knob under the handle.

Static display consisting of labels representing different types of clothes.
Texture around to ease rotating.

- **Steaming and spraying:** none

Modification: none
Length of ownership: 15 years.

Table E.1: INTERFACE ANALYSES FOR IRONS

USER J **Beko 1126**



- **Adjusting temperature:** multi-rotation rotary knob over the water tank under the handle.

Static display consisting of symbols representing different temperature ranges.
Raised mark of triangle on the water tank next to the knob to identify the position of the knob**.**
Texture around for easy gripping.

- **Adjusting steam power:** four-position rocker switch labeled with numbers and a symbol of steam.

One of the positions turns off the steam function.

- **Steaming and spraying:** identical adjacent alternate push buttons positioned close to where thumb will stand.

Graphic symbols printed on the front of them.

- **Power light** aligned with steam switch and push buttons on the handle.
- **Water tank:** two transparent stripes on the tank.

Modification: none
Length of ownership: 4 years.

Table E.2: OBSERVATION FINDINGS FOR IRONS

STEPS OF THE TASK	USER A *Philips Azur Cassetta 50*	USER B *Braun Optistyle*	USER C *Tefal Aquaspeed 120*	USER D *Rowenta Trio Inox*	USER E *Rowenta Professional*
					
Preparation/ Setting up	Sets the ironing board easily.	Already set up.	Searches for the iron for a while.	User is left handed so sets the board so that ironing with left hand would not be difficult.	Assistance from daughter in setting thee ironing board.
Filling With Water	Not observed. Has already water in the water tank.	1. Grips and opens the cover of the water fill opening at first attempt. 2. Holds left index finger in the opening to prevent overflow. 3. Pours the water without spilling.	1. Holds the iron with her right hand propped it up with the edge of the oven and holding right thumb in the opening. 2. Pours the water and water spills over. 3. Takes the iron on the countertop and filling successfully.	1. Grips the spraying apparatus with right hand and taking it out to reach the water fill opening. 2. Pours the water in the container using left hand into the opening. 3. Uses the right thumb and index finger to perceive the level of water. 4. Replaces the spraying component of the iron with left hand.	1. Fills boiled water into the opening with the left hand. 2. Not use finger in the perception of water level. 3. Water overflows.
Temperature Control	*Not use the temperature settings.* *Demonstrates upon request:* 1. Finds the selector by touching directly, without moving fingers over the iron. 2. Turns the temperature selector to the right until the iron turned off *Knows:* *Rotating the selector to the right turns off the iron and rotating the left turns on and increases the heat.* 3. Gets the selector between two ends 4. Controls the heat of the iron by touching the soleplate lightly.	*Knows:* *Turning the selector to the right increases heat, and turning to the left decreases heat.* Makes an average setting presumably. Not benefit from raised arrow to indicate the positioning of the selector.	Irons without adjusting settings except for steam adjusting. Uses the same temperature which was set previously for all clothes. Not know which setting is what for kind of clothes.	*Not use the temperature settings.* *Demonstrates upon request:* 1. Grips the selector from over the holder with left hand. 2. Turns the selector to the left until the end. *3.* Turns the selector to the right until the end. *Knows:* *Rotating the selector to the left turns off the iron and rotating the right turns on and increases the heat.* 4. Turns the selector a bit to the left and stopped between somewhere two and three. *Knows:* *Amount of rotation necessary to get the selector between the levels two and three.*	Not observed. Can not use. Daughter or husband sets the selector.
Handling and Ironing	Unfolds the cloth and stretches it to the board with left hand.	Moves the nose of the iron with small movements to the left and the right.	Moves the iron in a direction linear and randomly.	Moves the iron back and forth by directing it with left hand. Controls the pants with right hand.	Moves the iron in a direction horizontal with the ironing board.
Steaming and Spraying	1. Finds the selector by touching at first attempt. 2. Turns the selector to right until the selector does not move any more *Knows:* This is the initial position of the selector. 3. Turns it to the right once and setting the steam first level.	Not observed.	Turns on steam function during ironing.	Not observed. Iron steams automatically.	1. Turns the steam by pushing down the slide switch on the side of the iron by right thumb. 2. Pushes the button over the handle by right thumb to increase the steam.

Table E.2: OBSERVATION FINDINGS FOR IRONS

STEPS OF THE TASK	USER F *Rowenta Professional*	USER G *Tefal Supergliss 10*	USER H *Teknur*	USER I *Rowenta*	USER J *Beko 1126*
					
Preparation/ Setting	Spends a few minutes to look for extension cable.	Not use the ironing board.	Unfolds the ironing board by herself without problem.	Gets help in plugging and setting the ironing board.	Prepares the board and cloth to be ironed. Plugs without trouble.
Filling With Water	1. Grasps the front of the iron. 2. Perceives the opening by groping. 3. Pours the water in the container into the tank successfully.	Not observed. Has already water in the water tank.	Not observed. Not steam iron.	Not observed. Broken spraying mechanism	1. Holds the iron with left hand, 2. Pours the water in the teapot into the opening with her left hand without spilling over the water.
Temperature Control	*Not use the temperature settings.* *Demonstrates upon request:* 1. Turns the selector CCW to the end of the switch to power off. *Known: device is off at that position* 2. Turns CCW a while and stopped somewhere between middle point. 3. Adjusts an average temperature roughly. The increasing heat of the soleplate is a feedback to understand the temperature of the iron.	*Not use the temperature settings.* *Demonstrates upon request:* 1. Turns the selector CCW to the end of the switch to power off. 2. Sets the temperature highest setting as turning the selector clockwise to the end. Understands if the iron is turned off or not due to the sound of the selector.	Looks for the letter “K” on the temperature selector. Yet, there was no any letter including “K” on the selector. Neither visual nor haptic indicator on the control as well as around the control. Sets the selector to the highest level by controlling the heat of the iron.	Holds the iron with right hand. Grabs the temperature selector with left hand. Moves the selector to the left and to the right little. Yet, not change the position. Keeps the same setting. Not know accurately which position refers to which kind of cloth. Keeps the heat of the iron between two extreme positions of the selector. Understands the iron reaches desired heat by feeling the temperature of the iron.	Controls the heat of the iron by touching the soleplate lightly.
Handling and Ironing	Moves the iron back and forth.	Shifts the iron back and forth in a horizontal direction as general displacement. The t-shirt was wrinkled because of nose of the iron.	Duration of ironing relatively very long. 1. Spreads out a damp fabric upon the cloth to be ironed to prevent the shirt from burning. 2. Moves the iron back and forth in the direction horizontal with the ironing board.	1. Perceives the t-shirt to be ironed by groping. 2. Irons with her right hand straighten the cloth with the left hand. Damages the pattern of the t-shirt due to the high temperature of the iron.	Uses both hands to direct the iron. Holds other hand in front of the iron to be certain the cloth is not wrinkled. Moves the iron back and forth in the direction horizontal with the ironing board.
Steaming and Spraying	Not observed.	Sets the steam on by pulling the switch with right index finger, while holding the iron with this hand.	No steaming and spraying function.	Broken spraying mechanism.	Faces difficulty in pushing the steam button. Changes easily the position of the steam power switch.

Table E.3: INTERVIEW FINDINGS FOR IRONS

QUESTIONS	**USER A** Philips Azur Cassetta 50	**USER B** Braun Optistyle	**USER C** Tefal Aquaspeed	**USER D** Rowenta Trio Inox	**USER E** Rowenta Professional	**USER F** Rowenta Professional	**USER G** Tefal Supergliss 10	**USER H** Teknur	**USER I** Rowenta	**USER J** Beko 1126
Which interface components or features are useful to you or make the appliance easier to use?	The gradual steam switch. Removable water tank.	Light weight which allows ease in control. High ironing performance due to a fine soleplate. Ease in filling the water tank.	High ironing performance. Handle design that allows a good grip.	None.	Having a steam on/off switch. Having a spraying function.	None.	High ironing performance.	High and lasting ironing performance.	None.	None.
Which interface components or features make the appliance more difficult to use?	Temperature selection is difficult because the selector lacks an auditory feedback.	Temperature selection is difficult because it is not possible to select a precise temperature level according to cloth type.	Temperature selection is difficult because it is not possible to select a precise temperature level according to cloth type.	Temperature selection is difficult.	Temperature selection is difficult.	Temperature selection is difficult because comprehending the selector is problematic.	Temperature selection is difficult because the selector cannot be operated properly.	Temperature selection is difficult because the selector has inadequate marking.	Almost all the components of the iron are unusable.	The water fill opening is narrow. Temperature selection is difficult because the selector has inadequate marking. Steaming button is difficult to push.
For a visually-impaired user to be able to use an iron adequately, which changes should be made in the design of the iron?	Temperature selectors might generate an auditory feedback, or a discrete selector with definite positions might be used.	Temperature might be set by using different push buttons for different levels of temperature. Water tank might give an auditory feedback when it is full.	Temperature selector might have raised marks or letters on or around it. A full manual in Braille alphabet might be included in the appliance.	Temperature selector might have raised marks or letters on or around it.	Temperature selector might have raised marks or letters on or around it.	Switches might have auditory feedbacks. A discrete temperature selector that generates an auditory feedback at each position might be used.	Temperature might be set by using different push buttons for different levels of temperature.	Temperature selector might have raised marks or letters on or around it.	Appliance might give spoken feedback on the steam power and the temperature of the iron.	Water fill opening should be larger. Temperature selector might have raised marks or letters on or around it. Buttons should be easier to push