THE EFFECTS OF ICON DESIGN AND BACKGROUND COLOR ON VISUAL SEARCH PERFORMANCE AND USER PREFERENCES

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ABSTRACT

THE EFFECTS OF ICON DESIGN AND BACKGROUND COLOR ON VISUAL SEARCH PERFORMANCE AND USER PREFERENCES

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One of the most crucial points for the graphical user interfaces is that visual information on the screen must be perceived accurately, fast and effortlessly as much as possible. However, perceiving visual information accurately and finding their location on the screen requires some visual search even in familiar operating environments. Thus, visual search performance is an effective way in order to measure the effects of different visual presentation on users' processing speed. In the present study, the effects of two variables that may affect visual search performance which are background color of interface and figure/background contrast ratio as a feature of an icon design are investigated through two background color and four icon design alternatives with 83 participants. As a result of that, both task completion time and users' subjective preferences were gathered to assess the effects of visual presentation thanks to the software developed in order to store logs of task completion time and users' preferences.

The results of the experiment revealed that;

- The background color of an interface and icons has crucial effects on visual search performance.

- There is a significant interaction between users' preferences and background color. Icon sets without backgrounds are evaluated with higher ratings on dark themes.

- There is not a direct correlation between visual search performance and users' preferences in terms of icon design. The alternatives which were evaluated with higher subjective ratings are not necessarily distinguished with the task completion time.

Keywords: Visual Search Performance, User Preferences, Icon Design, Background Color, Contrast Ratio

ÖZ

İKON TASARIMI VE ARKAPLAN RENGİNİN GÖRSEL ARAMA PERFORMANSI VE KULLANICI TERCİHLERİ ÜZERİNDEKİ ETKİLERİ

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Grafik kullanıcı arayüzleri için ekranda sunulan görsel bilginin, kullanıcılar tarafından doğru, hızlı ve mümkün olduğunca az çaba harcanarak anlaşılabiliyor olması son derece önemlidir. Ancak, kullanıcıların aşina oldukları grafik arayüzlerde bile sunulan bilgilerin doğru algılanması ve ekran üzerindeki konumlarının bulunabilmesi, belirli bir görsel arama süreci gerektirir. Bu nedenle, kullanıcıların görsel arama performanslarının incelenmesi, ekran üzerindeki farklı görsel sunumların kullanıcıların görsel arama süreleri üzerindeki etkilerinin ölçülebilmesi için en etkili yoldur. Tez araştırması kapsamında sunulan bu çalışmada, kullanıcı arayüzünün arkaplan rengi ve grafik ikonların tasarım özelliği olarak figürün arkaplan ile yaptığı kontrast oranı gibi iki farklı değişkenin kullanıcıların arama performansları ve kişisel beğenileri üzerine etkileri; 83 katılımcı ile birlikte 2 farklı arkaplan rengi ve 4 farklı ikon tasarım alternatifi üzerinden test edilmiştir. Bu amaçla kullanıcılara belli görevler verilmiş, görev tamamlama süreleri ve ikon tasarımlarımı için yaptıkları kişisel puanlamaların kayıtları bir test yazılımı yardımıyla kayıt altına alınarak, varyans analizleri yapılmıştır. Sonuçlar göstermiştir ki;

- Kullanıcı arayüzünün arkaplan rengi ve ikon tasarımına bağlı olarak ortaya çıkan kontrast oranının kullanıcıların görsel arama performansları üzerinde etkili olduğu görülmüştür.

- Kullanıcıların koyu arkaplan üzerindeki ikon gösterimlerini anlamlı bir şekilde daha çok beğendikleri incelenmiştir. Bu da arkaplan renginin kullanıcı tercihleri üzerindeki etkisini ortaya koymaktadır.

- En iyi arama performansında sahip ikon setleri ile en çok beğenilen ikon setleri arasında farklılıklar gözlenmiştir. Bu da kullanıcı performansı ve kişisel tercihleri arasında doğrudan bir korelasyon olmadığını göstermektedir.

Anahtar Kelimeler: Görsel Arama Performansı, Kullanıcı Tercihleri, İkon Tasarımı, Arkaplan Rengi, Kontrast Oranı

Dedication

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CHAPTER 1

INTRODUCTION

User interface is a tool that enables users to control the physical devices or software that they are interacting with. User interface of software consist of graphical controls like windows, toolbars, buttons, icons, etc. in order to enable users to interact with them, so such interfaces are defined as graphical user interfaces (GUIs). User interface of physical devices may include a set of physical buttons for interacting with them such as remote controllers. Both physical and GUIs are crucial in order to enable software or hardware to perform their functions properly. In terms of providing communication between users and product, if the interface elements are designed successfully, it would affect products' performance and users' experience positively. For example, a door handle can be described as the user interface of a door to open or close it, so the form, weight and position of a handle would affect users' interaction. Thus, designers pay attention to ergonomics standards like ease of use, safety, comfort, performance, etc. in order to provide the best interaction for users since the users' experience with those products is one of the crucial factors for market success. However, usability principles for GUIs of software are different from a physical products', because users interact with a digital screen rather than an entire physical product. In fact, with the invention of personal computers, the new area with new challenges occurred for user interfaces because computers have opened doors to the new digital world which would be unfamiliar for users. In that, the complex and multifunctional structure of computers would make it harder for user interfaces to communicate with users in order to inform and enable users to control computers' functions. Moreover, for the users who know the structure and operating system of computers well, it would be

clearer to interact with computers, but this new digital world was completely unfamiliar with most of potential users of computers.

Therefore, in order to provide a familiar environment for users and to make user-interaction natural, GUIs frequently imitate the real world by using the representations of graphical objects on the screen. For example, the first GUI that was used in Xerox Alto was developed by imitating office desk in order to benefit from metaphors thanks to using graphical symbols like a notepad, recycle bin, calendar, etc. as Smith (1982) stated. Thus, the users would see the imitation of their real desktop on the computer screen and, for example, select the notepad on the screen to take notes. As a result, benefiting from metaphors while designing GUIs was the effective way of providing familiar environments for users in order to improve usability of systems. Otherwise, making users to face with complex background process of computers in order to interact with computers would affect users' interactions negatively in terms of predictability of functions.

Therefore, it seems that creating familiar environment for users through resembling real world as much as possible was popular approach, so the GUIs evolved from this aspect for a long time. Icons were the most crucial graphical elements of visual communication between users and computers, so the evolution of GUIs directly influenced icon designs. With the widespread use of GUIs over time, users' familiarity with the digital world also increased and the digital world gradually started to be separated from the real world. Thus, using simple and easy-to-understand icon designs came into prominence instead of icons which look realistic. As a result of that, similar to ergonomics standards of physical interfaces, the factors that would affect users' performance on GUIs started to be investigated because users' experience which depends on their interaction with the user interface would affect the success of the system, service or product especially for commercial websites because users' experience on such websites would directly affect the commercial success of a brand. Apart from that, the GUI of critical systems that users should not make any mistake during the operation would be more crucial in terms of users' performance like military, aviation or medical

systems. Thus, this study conducted with an electronic company which produces electronic warfare systems in order to identify the icon sets they would use in their systems to enhance users' performance because the icons are essential part of GUIs.

Nowadays, icon use in GUI becomes more and more popular on due to prevalence of mobile devices and applications. There are three main advantages of icons which make them indispensable for all kind of GUIs. First, the use of icons in user interfaces requires less space than written descriptions. Second, Gittens (1986) stated that it eliminates language barriers in user interfaces thanks to universal language of images. Thus, the use of icon might be inevitable for crowded screens and an interface would be used by people from different countries.

One of the most important advantages of icon use is that it provides fast transfer of information to the user as it is easier to distinguish and select a correct icon than written descriptions (Huang, 2008). Also, as Lindberg (2003) states, it is crucial that visual information in the GUIs perceived as fast and accurately as possible without causing any mental fatigue. However, users are usually exposed to a lot of visual information from GUIs especially in complex interfaces like the ones used in military systems, so their visual search performance is important because the perception and selection of visual information even in a familiar use environment requires visual search. Thus, investigating users' visual search performance is the effective way of measuring users' task completion time, so this study was planned in order to investigate the effects of icon design on users' visual search performance.

There are also some studies in the literature which investigate the effects of color and background shapes of icons on users' search performance and preferences that were conducted by LUO & ZHOU (2014), Lindberg & Nasanen (2003), Huang (2007). However, since the alternatives which are tested in these studies are usually extreme examples such as comparison of icons with big triangular backgrounds or icons with very low contrast, so can only reveal the presence of an effect, but they

cannot help enough in a choice made from realistic alternatives. Therefore, this study focus on comparison of reasonable icon designs which are designed considering previous studies in order to provide useful alternatives for any GUIs that have similar criteria or limitations. In other words, thanks to comparison of reasonable alternatives which are designed through the results of previous studies, studies about this subject would be taken one step further in terms of revealing application of previous studies' outputs on real icon design. Also, various useful design alternatives would be derived in the light of the results in the future. Moreover, different from other studies, icons will be tested on both dark and light themes, so the results would be beneficial for GUIs which same icon sets are used on both night and light mode. Then, the best alternative that would enable users to find any function which they are searching on the screen fast as much as possible will be explored because search performance of users is crucial for some systems that users should control fast without any mistakes like medical, military, aviation etc.

1.1 Aim of the Study

There are various factors that affect users' search performance on GUIs, but color, contrast and icon types can be considered as the most important according to Huang's (2008) study. The aim of this study is to explore the effect of icon design together with background color of GUI on users' visual search performance and preferences.

This information will be useful to understand whether it is possible to increase users' performance by changing the icon design and background color in GUI because using easily distinguishable icons in any GUI is an important factor in terms of ease of use.

As a result of the study, beneficial information would be provided for design of similar GUIs through comparing realistic combinations with icon design and

background colors in terms of providing better visual search performance for users. Also, investigation of correlation between users' preferences and their performance would be evolved into a study that would investigate effects of users' preferences on their learning speed with further research that would be beneficial for various sectors.

1.2 Scope of the Study

The starting point of this thesis was to investigate whether it is possible to increase the visual search performance of the users by icon design in the GUIs of a company producing electronic warfare systems. However, this study was carried out as an isolated test of icon designs because there are many factors that would affect the performance of the user in real GUI and prevent us from finding out only the effect of the icons. Therefore, the scope of this study covers not only military systems but also systems with similar criteria such as aviation systems, medical systems where users' performance is important. In other words, the results of this study would cover graphical user interfaces of electronic systems that users' performance is important.

Also, user performance is considered as only visual search performance in this isolated this study, because there are many variables that are difficult to control if the icons would be tested through a real GUI. Moreover, testing of alternative icon sets on both dark and light themes in this study would reveal crucial results for GUIs that same icon set is used for both day and night mode.

1.3 Research Questions

- What are the effects of color use in icon design in GUI?
- What is the effect of background color and figure/background contrast ratio on visual search performance?

- Is it possible to design an icon set that would provide similar visual search performance on both light and dark themes?
- What is the effect of icon design and background color on users' preferences?
- Is there any correlation between users' visual search performances and their preferences?

1.4 Structure of the Thesis

The present thesis consists of five chapters to include the following work and information.

Chapter 1, *Introduction*, introduces the research area of GUI and icon use in GUI. It also introduces the aim, scope and the research questions.

Chapter 2, *Review of Icon Use in GUI and Evolution of Icons*, includes explanation of terms of GUI and graphical elements of GUI. Also, explanation of usability in GUI and its measurability is observed in this chapter. Moreover, evolution of icons and previous studies about effect of icon design on users' performance are explored.

Chapter 3, *Methodology*, includes the explanation of the chosen methods to carry out the research as well as the proposed data gathering and data analysis methods.

Chapter 4, *Study of the Effects of Icon Design and Background Color on Users' Visual Search Performance and Preferences,* presents set up and the procedure of the empirical study that was conducted in order to reveal effects of icon design and background color on users' performance and preferences. It also presents the analysis and the results of the study.

Chapter 5, *Conclusions & Discussion,* offers direct answers to research questions, as well as discussion about results of study occur in order to interpret some

controversial points to shed light on further research about similar topics. Limitations of research are also discussed in this Chapter.

Figure 1.1 Representation of structure of the thesis by the author

CHAPTER 2

METHODOLGY

2.1 Introduction

The icons are the most common language of new digital world because almost all information can be represented by icons without facing any language barriers in accordance with the statement of Bocker (1993). Therefore, the use of icons has been accepted as a language of digital world. However, the real world was the first reference of this new structure in the beginning. Creation of icons resembling real life aimed at providing users with familiar environment to benefit from their previous experiences as stated by Rigou, Spiliotopoulos, Sirmakessis (2018) , but over time, the real world metaphors started becoming insufficient to meet the requirements of the digital world and new criteria for visual designs became necessary. Following this, users' performance came into prominence for graphical user interface (GUI) design. As the first step, understanding the meaning of icons intuitively by users became focal point for designers. However, new research on this subject led to occurrence of new design trends which aim to convey message with minimum visual details as much as possible without making effort to imitate real world with realistic visuals as Johnson (2013) explained.

The aim of this minimalism in visual design was to prevent the distraction caused by crowded visuals and to enable users to find the visuals that they are looking for with less effort. It is crucial that visual information in GUI in terms of providing better communication between user and system for better user experience. Therefore, the graphical user interface should be perceived accurate and fast as much as possible. Thus, visual search is crucial even in familiar digital environments r to understand the presented visual information and to find their

specific locations on the screen. Nielsen and Levy (1994) stated that measurement and users' objective performance and subjective preferences are two main parameters of measurable usability. Thus, measuring the users' visual search performance is an effective way of understanding effects of different visual presentation.

Therefore, the current research is conducted in order to understand the effect of icon design and background color on users' visual search performance and preferences. The aim was to prepare a guideline for designers about icon design for GUI that users should interact with fast like military systems, medical systems, aviation systems etc. Also, the study would show whether there is a correlation between users' performance and preferences, so it will be an important data for companies to agree with its customers on a specific design in their projects. To gather such information, this research consists of two main steps: (1) literature review, and (2) experimental study, which are now going to be introduced in more detail.

2.2 Research Methodology Overview

In this section, content of the literature review and reasons for conducting an experimental study will be explained. The research questions are;

Q1: What are the effects of color use in icon design in GUI?

Q2: What is the effect of background color and figure/background contrast ratio on visual search performance?

Q3: Is it possible to design an icon set that would provide similar visual search performance on both light and dark themes?

Q4: What is the effect of icon design and background color on users' preferences?

Q5: Is there any correlation between users' visual search performances and their preferences?

Methods and results of the relevant studies in literature related to Q.1 and Q.2 will be examined in order to reveal answers of similar questions in literature, and collect useful information for the construction of this test study because the results of similar study might be guiding for this study. Moreover, a literature review will be carried out to reach similar studies related to Q.3, Q.4 and Q.5, but the exact results will be statistically revealed with the experimental study to be performed on the icon sets and background colors designed for this test study. Also, if similar studies can be found in the literature, the results of these studies will be utilized in the design processes of the alternative icon sets will be tested on this study.

2.3 Literature Review

In order to provide a basis for this study, first, a literature review was carried out into what is graphical user interfaces (GUIs) and what are the visual elements of GUI. The review also included what usability principles should be taken as a guide while designing GUIs, and for icons as a visual element to be most effective. In addition, the evolution of icons, the main design trends that emerged during this process and the focal points of the trends were investigated since the first examples of GUIs in order to provide basis for icon designs that would be tested in this study. Finally, in the review, similar studies carried out so far have been analyzed in depth in order to benefit from their conclusions and to identify further opportunities to research. As a result, required information for the planning and design of the test was gathered from literature.

2.4 Experimental Study

Nielsen (2001) states that what users do is more crucial than what users say because a good-looking design can be misleading about users' ideas, so its usability and users' performance will only be revealed during utilization. Also, Nielsen (2001) defines rules of usability as observing what users actually do, not believing

what users say they do, and not believing what people predict they do in the future. Therefore, quantitative research methods would be more suitable for this study in terms of evaluation of users' performance depending on measurement of their task completion time, so gathering numerical data about their performance would be purposeful to understand effects of variables on their performance. Besides that, in order to reveal effects of same variables on users' preferences and explore whether there is a correlation between their performance and preferences, using the same method would be useful to achieve more consistent results.

To measure the effect of defined variables on users' performance quantitatively, conducting experimental study is decided as the most suitable choice. In experimental study, one of the variables is kept constant and the other is changed in order to reveal performance differences depending on changes by testing on users. As stated by Rohrer (2014), usability of alternatives can be benchmarked by performing such a test with users that uses predetermined measurement for performance. Moreover, Nielsen (2005) defines one of the benefits of this method as it can reveal even the smallest performance differences statistically.

Moreover, Bevans (2020) explained the research method of experimental study as a manipulation of independent variables on to measure their effects on dependent variables. However, relationship between variables should be understood well to make reasonable prediction before experiment design for good experimental study. Thus, manipulation of independent variables would be more reasonable for consistent results. According to research questions of this study, icon design and background color will be independent variables while evaluation ratings and task completion time will be dependent variables. Also, the correlation between evaluation ratings and task completion time will be revealed with this experiment. In order to explore that, method of repeated measure design will be used while assigning tasks to participants during experiment. Repeated measure design means that each participant attends to experiment consecutively. Then, participants' responses are measured to understand the effect of manipulated variables. For this method, according to Bevans (2020), counterbalancing which is randomization of

treatment order is crucial to get reliable results. Thus, the experiment can be designed to explore subject of this thesis by considering the requirements of this method.

Therefore, for this study, different icon sets will be designed in order to measure their effects on users' performance and preferences. The icon designs will be manipulated during the test session of each participant. To achieve that, the test software will be programmed to store users' task completion time and subjective evaluation ratings about different icons sets while the participants are trying to find and select target icons between distracters. In this way, effects of icon design and background colors will be explored thanks to changing icon design and background color for each demonstration. For design of this experiment, there are some crucial points which should be considered. For example;

- The demonstration that participants will try to find target icon between distracters should be repeated for different icon sets on different background in order to compare the effects of different icon designs and background color.

- Target icon must be same in each demonstration to be able to focus on only the effects of icon design and background color. Otherwise, the results of study would not be reliable because using different target icons will be another variable that will affect participants' reaction time due to characteristics of icons.

- Numbers and types of distracter icons must be same for each demonstration in order to provide equal level of difficulty.

- Size of a target icon and distracter icons must be the same to not to affect reaction time of the participants. Also, icon sizes to be selected should be compatible with 15 to 24 inch monitors as the results of the study do not cover the mobile applications.

- Color schemes of a theme and icon designs need to be selected to be compatible with GUI of systems that users' performance is crucial such as medical, aviation and military systems. Therefore, color options should be limited according to

structure of such GUIs. For example, red, green and yellow are mostly used to indicate system status, warnings, errors, etc., so these colors should be used carefully.

- The distance between cursor and icons must be same for each demonstration, so using circular array and positioning the cursor at the center of this array at the beginning of each demonstration would be a logical approach.

- The shape of a target icon should not look very similar to other distracters because this may cause confusion and affect participants' reaction time.

- This test should be conducted in a controlled room to use the same set of equipment for each participant and to avoid any distractions from the environment.

2.5 Data Collection Methods

In order to investigate the effects of different icon designs and background colors on users' performance and preferences, a test will be designed to compare users' performance according to their task completion times while searching for a predetermined target icon between four different icon sets that are shown on both dark and light background. Meanwhile, the test software will record the task completion time of the participants for each step and keep it simultaneously as an Excel spreadsheet. At the end of the test, the participants will be asked to evaluate eight icon set alternatives according to their subjective preferences by indicating on a 5-point Likert scale (1 being the worst and 5 being the best) (see Appendix B) The ratings will also be recorded by the test software. In accordance with the nature of experimental study, the effects of variables (icon design and background color) can be examined by keeping the target icon constant while changing the icon set and background color at each step.

2.6 Data Analysis

The results of the study will be analyzed with technique of ANOVA (Analysis of Variance) that is used in order to investigate whether there are significant effects of independent variables on dependent variable. For example, task completion time will be defined as a dependent variable while icon designs and background colors will be independent variables for this study.

To carry out the analysis, the records of the participants' completion times and ratings of subjective evaluations will be added to the excel chart separately for eight steps of test which consist of representation of four different icon sets on different background colors for each participant. Then, the ANOVA will reveal whether there are statistically significant differences depending on variables or not.

Therefore, the statistical results obtained from this analysis will reveal the participants' performance data and their evaluations according to their personal preferences about different icon sets. The results will also enable to understand the relationship between the participants' performances and preferences.

CHAPTER 3

REVIEW OF GUI DESIGN AND EFFECTS OF ICONS

3.1 Introduction

In this chapter, what the GUI is and the importance of the GUI in terms of interaction between the product and the user will be mentioned in general. Then, principles that would affect usability in GUI will be discussed. After that, the icons, which have a direct effect on the principles of usability in GUI and as the main subject of this study, will be examined in more detail. Moreover, the characteristic features of the icons and their evolution with technological developments will be examined. After that, the studies which are investigating the effects of icons on users' search performance in the literature will be evaluated and the user will be warmed up for the empirical study.

3.2 Graphical User Interfaces

The widespread use of the internet and becoming part of our daily lives lead to increase in number of software companies all around the world. As Andreessen (2011) says software companies have become an important part of our lives and they dominate in different sectors like Amazon, Linkedin, Netflix, etc. Most companies started providing websites and applications to reach billions of people. Thus, people can now access a lot of information or they can shop from anywhere via internet from their computer or smartphones. Therefore, online platforms became a significant competitive environment for all companies. In this sense, graphical user interface (GUI) is a crucial element for companies to rise to prominence in their websites or apps because it enables users to interact and

communicate with a system or computer, and they affect users' experiences directly. Jansen (1998) states that GUI should provide practical and user-friendly medium for users to make them feel comfortable and positive towards the system, website or application, and to ensure marketing success. GUIs consist of windows, icons, menus, buttons, etc. which determine the characteristic of interface and performance of users. Carefully designed GUI has the potential to increase brand loyalty by improving users' perception via better user experience. For example, Winograd (1995) states that when the first GUI designs emerged in personal computers in 1980s, Macintosh users' loyalty to Apple was higher than windows users' loyalty to IBM, because Macintosh users' satisfaction with GUI of the system was higher than windows users. This is a good example that GUI design would affect the success of product or brand directly, but it is also hard to define ideal GUI design in terms of usability, efficiency, etc. Although there are a lot of studies focusing on different aspects of GUI design such as from its appearance to scenarios that it needs to be used, they may still vary according to types of software platforms they are applied (Jansen, 1998).

However, GUI can be described in different ways although there is no certain definition for what makes good GUI design. In simple terms, GUI is a visual interface that enables people and computer to communicate with each other and that enables people to command to software via its visual elements such as icons, windows, controls, and tabs. According to of Marcus (1997) visual elements include icons, menus, windows, tabs and controls explanations of which are given in the following.

Icons are small pictures which are used in GUI in order to represent some objects or functions of GUI. For example, clicking on the icon of recycle bin on desktop enables users to reach folder of deleted items. In other words, icons are used to provide communication between users and system to enable users to control the system.

Menus consist of list of choices about manageable functions of GUI. In this way, users can make a selection with cursor or finger on menus. “Menu Bar” and “Context Menu” are the two common types of menus. Menu bar is usually located top of the screen horizontally, and users can select options from here. Also, pull-down menus are preferred on menu bars. Context menus only appear depending on specific action like pressing right button of a mouse.

Windows are the essential structural elements of GUI which is used for displaying information on the screen. For example, after clicking on icon recycle bin, the window of recycle bin will be opened to display information of deleted items. Also, multiple windows can be opened at the same time in order to control different tasks. Moreover, windows’ size and location can be manipulated by users.

Tabs mostly have rectangular shape which includes text or icon. Tabs are usually located at the top of screen in groups in order to enable users to switch between different widgets. It is mostly used in web browsers such as Chrome, Firefox, Opera, etc. so users can switch between multiple pages thanks to taps at the top of browser.

Controls are the visual elements that provide interaction between user and computer in order to interact with the information on the screen by editing or reading. Also, in order to provide consistency on GUI in terms of interaction for users, same control elements are used to control similar type of information. For example, radio buttons, check boxes, scrollbars, sliders, tabs, etc. are commonly used control elements.

GUIs should be designed considering certain limitations that people may have. Wickens (1984) states that one of these limitations is for example, the visual limits of the human eye. Human eyes can focus on a small portion of a screen. Especially on wide screens, which are used to control machines, eye can only catch certain details at once. Therefore, usability considerations should be taken into an account and visual elements on GUI like buttons and icons should be designed carefully in terms of their size, position, color, etc. to not to cause any eye strain. Another

limitation is the amount of information people can process at once (Jansen, 1998), for this reason, the number of options on menu and icons are important criteria for successful GUI design. However, it is not easy to evaluate usability features of an interface or a product without conducting user tests such as, measuring the users' task completion times. Therefore, designers may face with difficulties while convincing other stakeholders during the project process about their design decisions. In order to improve product or software in terms of usability, user test is crucial. According to Ehn and Löwgren (1997), engineering success of a project can be evaluated with time and cost of the development process, so in order to evaluate usability of the project, measurable aspects of usability can be explored like task completion time, reaction time, search time, etc. Therefore, users would be taken into the focus of the design process of a GUI to understand user needs and possible tasks that users would perform via GUI, so these tasks might be analyzed in terms of completion rate, time, etc. in order to make usability of GUI measurable. In other words, during the design process, important design decisions should be tested with users in order to prevent developers from returning previous steps in the process, and produce a successful product at the end. However, measurable usability goals must be determined before testing them with users. For example, user performance, flexibility, learnability and users' preferences can be described as most popular examples of a measurable usability for GUI design as Ehn and Löwgren (1997) stated. For the measurable test of user performance, specific task can be defined for users on GUI, and users' completion time and error rates can be measured to understand whether GUI has designed compatible with users' capability, and it satisfy users' needs. Therefore, people for test group can be chosen from different segments of population in order to test flexibility of interface design, but if the graphical user interface will be used by specific group of users, testing of flexibility might be useless. Apart from that, performance test can be repeated with same user group in order to understand learnability of GUI design. Different from these example, users' subjective preferences are important to improve users' performance, but its measurement is different from others because

its test depends on interviews instead of tangible tests like completion time because aesthetic aspect of user interfaces depends on individual thoughts and experiences. Users' previous experiences are crucial in terms of addressing their use habits in design of GUI because people are surrounded with a lot app, websites, software, etc. that include similar navigation system, menu structures, and button types, so they have their own use habits according to that, so they would expect to see similar structure in any kind of graphical user interface. Thus, pursuing the usual structures for GUI design and usability heuristics would be useful to meet users' expectations.

3.3 Usability Principles

Nielsen (2012) defines usability as an effort to develop user interfaces that would be used easily by users. In other words, it can be defined as method of providing ease-of-use. Also, according to him, usability can be evaluated according to 5 criteria which are learnability, efficiency, memorability, errors and satisfaction.

Learnability means that how easy users can be adapted to the design when they encounter it first time, so providing users familiar environment would be beneficial to improve learnability of a GUI

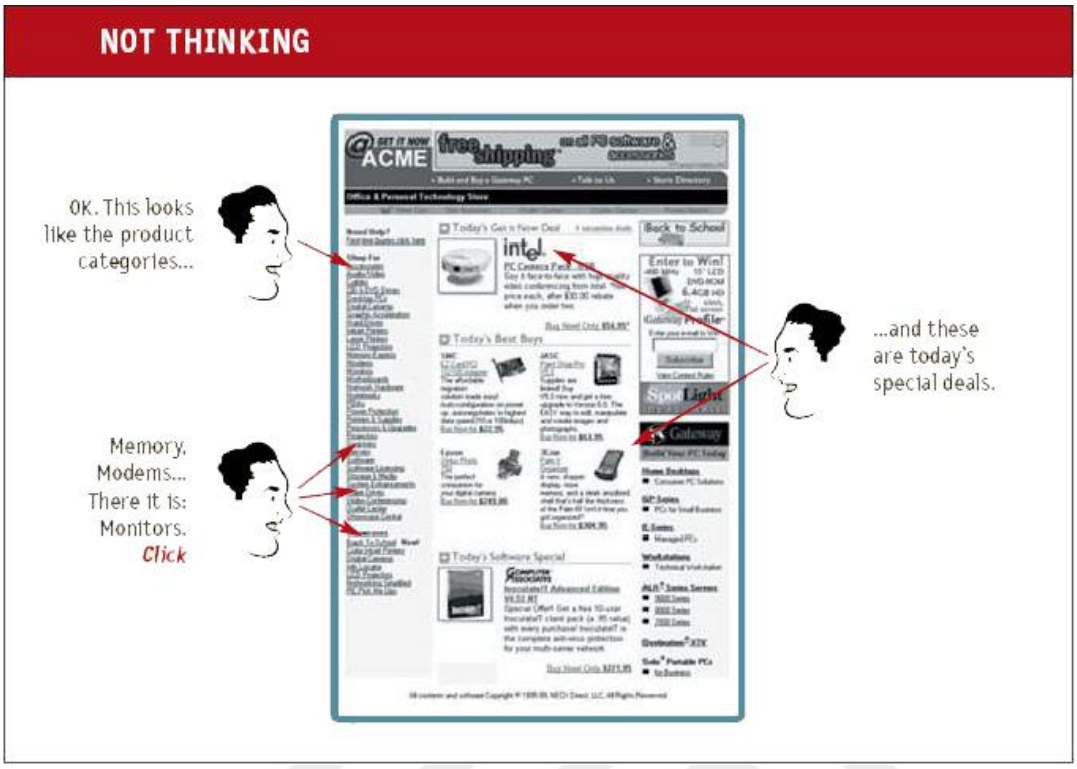


Figure 3.1 Example of how users interpret the layout of a GUI (Krug, 2013)

In this way, users would interact with GUI easily and fast thanks to their previous experiences about similar interfaces. Different from that, uncommon page layout would make users think more, so it would increase their mental fatigue and lower their performances.

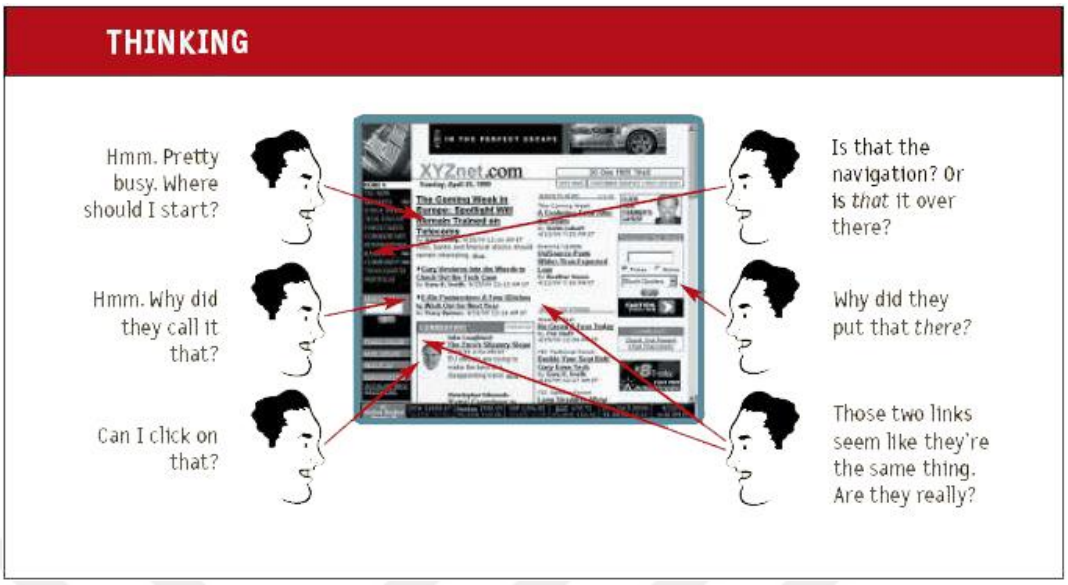


Figure 3.2 Example of a conflict unfamiliar layout of a GUI might cause (Krug, 2013)

Similar to uncommon page layout, other visual elements like buttons and descriptions would have the similar effect on users' interaction. These types of confusions would cause serious problem for commercial websites and applications because the first impression would be crucial to attract user attention, so their use habits and expectations would affect their experience with GUI. However, this effect can be overcome by the learning process on system interfaces with long-term use, the effect of screen design on user experience.

Efficiency refers users' task completion time after they get used to the design. Also, a good GUI design would have significant effect on the performance of user and system. Moreover, there are a lot of studies that show that screen design would affect users' performance. For instance, Tullis's (1981) study shows that redesign of the interface of a system that enables user to test telephone lines increased users' performance, and lead to save 40% of time by increasing the intelligibility of the display. Another study, by Tullis (1984) again, carried out over 500 screens which show information about airline and accommodation showed that there is a difference of 128% between the best and the worst of different screen designs used

for same system in terms of user performance. Moreover, Keister and Gallaway (1983) found that a new screen design for a system made 25% reduction in completion time and error rates. Also, Donner, McKay, O'Brien and Rudisill's (1991) study about redesign of space shuttle screens revealed that screen design caused %28 reduction in users' search time for finding specific information on the screen.

Memorability means that how easy users can perform again after not interacting with the same design for a long time.

Errors refer users' error rates during performing a task.

Satisfaction refers users' personal opinions and feelings while interacting with the design.

According to these criteria, any usability problems would cause trading loss for commercial websites. In other words, if users cannot interact with the website properly, they would not like this experience and they would not have dealings. For example, if users cannot easily find what they are looking for on a website and get lost, they will leave this website and turn to alternative ones. Besides that, usability problems in user interface of a system or a product would affect productivity of the system and users negatively. Moreover, especially for user interface of a system that operator should not make any mistake during the operation like military or medical devices, usability problems would cause dangerous situations. As a result, usability is a crucial factor for all types of user interfaces in order to improve productivity of a system or a product, so developers, designers or producers should attach importance to usability for their own success.

In order to provide better usability for user interfaces, users' natural behaviors and needs should be observed and analyzed properly. After that, almost each design decisions should be tested with users through prototypes. Although this process would be specific for each design, some general heuristics are also introduced by Nielsen.

1- Visibility of the status

The system should give feedback to users about what is going on within a sensible period of time by using colors, timer, etc. For example, while uploading a file to e-mail, the status of uploading is shown with a time bar, so user can be aware of what is going on while they are waiting for uploading.

2- Match between system and the real world

In order to provide familiar environment to users, systems should include suitable expressions for users' language instead of using systems-based language. For example, using terms of EFT (Electronic Funds Transfer) as a command of sending money in online banking applications would be confusing for users because this statement includes a technical language used in banking systems and it is not suitable for daily language.

3- User Control and Freedom

Users can often make some mistakes while interacting with a system, so the system should offer a chance of undoing such accidental actions freely. For example, users can delete a document on the desktop, so the system should enable them to recover it from recycle bin

4- Consistency and Standards

System should offer same visualization or interaction methods for same actions even on different pages. For example, color and shape of the button of confirm should be same on each page not to make users think twice.

5- Error Prevention

The system should be arranged to direct the user instead of giving an error message because systems that give too many error messages might make a negative impression on the user. For example, while typing something to search on Google, the system tries to correct spelling by showing similar search history.

6- Recognition rather than Recall

The system should suggest or show options or actions to users in order to decrease their memory load. For example, while typing something to search or some commands, system should suggest some possible results without waiting for the user to write the entire sentence.

7- Flexibility and Efficiency of Use

The system should be flexible about providing different options and interaction according to different user types like experts or normal users. Offering “default” or “custom” installation options while installing a software can be an example of this subject.

8- Aesthetic and Minimalist Design

The system should not show any irrelevant information or visual according to user interaction not to distract users. For example, Google shows only a search bar on home screen.

9- Help Users Recognize, Diagnose and Recover from Errors

Messages about errors on the system should clearly explain the problem and direct users for possible solutions instead of showing some codes that users probably would not understand.

10- Help and Documentation

Although, it is expected that the system can be used easily without need of help or documentation, but some tooltips can be beneficial in order to cover all users.

As a result, even though these usability principles cover the user interface more broadly, icons would make crucial contributions to satisfaction, memorability, learnability and efficiency of GUI as graphical elements. In this study, efficiency of icons by measuring reaction time of users during visual search and their satisfaction about design will be evaluated.

3.4 Use of Metaphors in GUI

In order to provide better user experience, it is crucial to benefit from metaphors not to make users think about usage of GUI as much as possible. Carroll and Thomas (1982) claimed that designers base graphical user interface design on framework that user already know in order to enable ease of use. Thus, it can be called as a GUI metaphor, and it is an effective tool in order to provide better interaction for users, so creating metaphors for user interface is a crucial challenge for human computer interaction design. There are several descriptions about metaphors. For example, Johnson and Lakoff (1980) described it as "understanding and experiencing one kind of thing in terms of another". Holyoak and Thagard (1995) described it as “cross-domain mapping”, so it enables users to transfer their prior knowledge about a familiar domain to unfamiliar domain that they would interact with. As a result, this would help them to improve their perception about an unfamiliar domain.

Collins (1995) explained this process as supporting of knowledge about target domain by source domain. As a result of these descriptions, GUI can be thought as a target domain for users, so benefiting from metaphors while designing GUI would be effective in order to provide people familiar and predictable interface environment. The most famous interface metaphor is the “desktop” metaphor because the first graphical user interface which was benefit from metaphors imitated physical desk of secretaries in terms of tasks, layout and objects in order to benefit from their prior knowledge and use habits. Smith, Irby, Kimball, Verplank, and Harslem (1992) claimed that literal digitization of their physical environment which includes folders, waste bin, documents, etc. would accelerate their learning process. With the extensive use of user interface, this concept has evolved to become more intuitive in order to improve usability more than learnability by using metaphors in a more abstract way. Thus, use of visuals on graphical user interfaces is crucial in order to provide users familiar environment to improve usability by benefiting from metaphors. Due to that, icons have become important visual

elements of graphical user interfaces because it affects user experience with interface and their performance, so there are a lot of research about effects of icons on users' performance form different aspects because software companies give importance to this issue in order to create their own icon and graphical user interface styles which help them to attract people attention and increase the loyalty of their customers.

3.5 Icons

Icons consist of two parts which refer visual and cognitive aspects of icon design. These features of icons would affect users' performance, and efficiency of graphical user interfaces in terms of usability and preferability. Color, size, shape and proportion of icons are evaluated as visual aspects of icons design, and semantic distance, concreteness, familiarity and complexity are evaluated as cognitive aspects of icon design. Effectiveness of icons can be measured with users' performance in terms of search performance and reaction time or their preferences in terms of their experiences. At this point, visual and cognitive aspects of icons have an important role in terms of users' perception which shows the effectiveness of icons.

There are many researches about cognitive features of icons that try to explore effect of each feature on users' performance. According to these researches, the term of familiarity refers that how often users have been seen similar icon type during their previous experiences. Apart from that, concreteness refers that the similarity between icons and real objects, so it refers more perceptible icon designs different from abstract ones. Another term which is complexity refers that excessive detail of icon design different from simple ones which have a few details. The last one which is semantic distance refers to similarity between icons' visuals and their functions in terms of metaphors.

3.5.1 Familiarity

Familiarity for icon design can be interpreted as a familiarity with the object imaged in the icon design or user's previous experience with same icons. Isherwood (2007) states that according to recent research, although the experiencing the same icons via series of trials might reduce its effect on users' performance, familiarity in the icons is crucial in terms of identification process. Moreover, Lambon-Ralph, Graham, Ellis and Hodges's (1998) research about picture-naming has revealed that familiarity enables users to reach their long term-memory easily, so it has a long-lasting effect in terms of icon identification. Hence, it would affect users' performance positively.

Home Page **Settings** **Save**

Figure 3.5. Examples of icons which reflects the characteristics of familiarity by the author

For instance, these are popular icon types that all users must encounter their daily lives, so they would have several experience with them to become familiar enough. Thus, they would interact with them easily in any kind of graphical user interfaces, so using these icons on GUI design would improve their performance. The icon of "save" is an important example in order to show effect of familiarity on users' perception because although most users of graphical user interfaces have never seen or used floppy disk in their daily lives, they would know that it refers a function of saving in any king of graphical user interfaces thanks to their previous and familiar experience with this icon design.

3.5.2 Concreteness

Moyes and Jordan thinks (1993) that it has a crucial effect on users performance and experience because imaging the real object on concrete icon design help user to benefit from their experience and knowledge about this object in their daily lives, so according to Stotts (1998) research, they would interact with GUI easily and fast. However, McDougall (2000) stated that advantage of concreteness on users' performance would reduce after they would gain experience with icons, so it does not have long-lasting effect like familiarity. Unlike concrete icons, Hourizi and Johnson (2004) state that there is no connection between real life and abstract icons, so it is more difficult for users to understand the function of abstract icons, so it seems that using concrete icons is a best way to improve usability of graphical user interface by benefiting from users knowledge about everyday objects while interpreting icons.

However, Stammers and Hoffman (1991) state that adding pictorial details to icons in order to make them resemble everyday objects would increase the complexity of icons. Thus, it is not easy to evaluate whether using concrete icons have performance advantages or it would increase visual search time because of its complexity. Byrne's (1993) research showed that graphical user interface which includes simple icons enable users to better visual search performance compared to complex ones. Thus, it is important to use concrete icons in graphical user interfaces in terms of making easy to interpretation of icons for beginners although it is not such crucial for users who have experience with same icons.

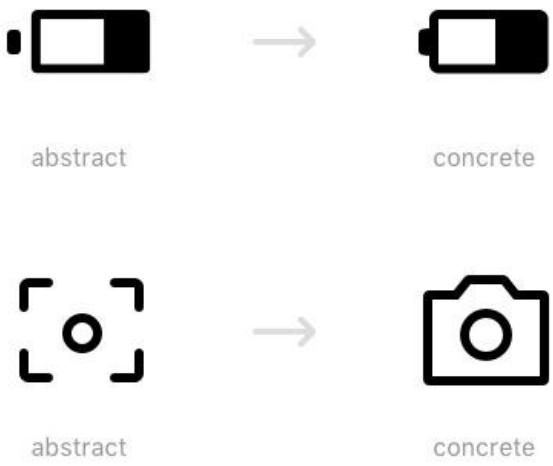


Figure 3.5. Examples of icons representation from concrete to abstract (McDougall, Curry, Bruijn, 1999)

Stammers and Hoffman's (1991) research shows that it is not easy to redesign pictorial icons suitable for abstract GUI concept, so according to Hourizi and Johnson (2004), benefitting from semantic distance rather than visual metaphors would be the alternative way of creating new icons.

3.5.3 Semantic Distance

Relationship between icon and its function can be defined as a semantic distance, so it might be crucial in initial learning process because it would help user to interpret meaning of icons easily. Also, Bates (2003) claims that it helps to reduce time of identification. However, after learning the connection between icon and its function, the effect of semantic distance would be reduced, and familiarity would be more important in terms of users' performance. Pierce (1932) divided semantic distance into three categories which are direct, inferential and arbitrary. Similarly, McDougall, de Bruijn, Curry (1999) defined connection between icon and its function from very close to distant like these three categories.

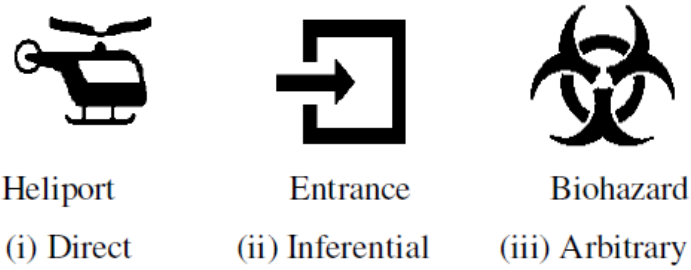


Figure 3.6 Examples from three categories of semantic distance (Gupta, 2018)

Goonetilleke, Shih, and Fritsch (2001) claimed that semantic distance has a more important effect on users' performance in terms of identification of icon compared to concreteness. Similar to that, Isherwood (2002) revealed that compared to concreteness, semantic distance is more effective on novice users' performance because while they are learning relationship between icon and its function, closeness between icon and function is more crucial than its pictorial look. Moreover, application of semantic distance is easier than concreteness because creating icons for abstract concepts would be really difficult by considering pictorial icon types, but icons do not have to be designed pictorial in order to apply semantic distance.

Butler (1996) stated that performance of a graphical user interface in terms of usability can be measured with time and accuracy of a specific task while users are performing because providing fast and efficient interaction is the most important mission for any user interfaces. However, Hassenzahl and Tractinsky (2006) said that aesthetic appearance of a graphical user interface might be such crucial that it might contribute interfaces' usability. Also, recent research revealed that there is a correlation between usability and aesthetics appearance like Lingaard amd Dudek's (2003) research. Moreover, Tractinsky, Katz, and Ikar's (2000) research reveal that interacting with an aesthetic user interfaces might lead users to make more effort to

learn and use it, so it would help to increase their performance. Moreover Tractinsky (2004) stated that the aesthetic appearance of a user interface would make people think positive about usability of it, too. Thus, icons are crucial to affect users' perception and performance because they are effective tools for aesthetic appearance of an interface, and also, they help to increase users visual search performance thanks to their distinguishability in an array as Byrne (1993) said.

There are two main design trends about styles of icons which are skeuomorphism and flat design. Spiliotopoulos, Rigo and Sirmakessis (2018) stated that skeuomorphism is the first design style of the icons which highly depend on metaphors and imitating everyday objects graphically. Different from that, trend of flat design focus on discovering the potential of digital life instead of imitating everyday objects graphically, and it becomes more and more popular in graphical user interfaces nowadays. Also, Johnson (2013) said that flat design is a trend which depends on simple 2D illustrations that includes simple lines and colors, and Basalla (1988) defined skeuomorphism as a trend of imitating physical world with 3d pictorial and graphically detailed icons in order to benefit from metaphors to improve usability by increasing familiarity. Thus, there is a conflict between these two opposite trends, but flat design is more commonly used in current graphical user interfaces.

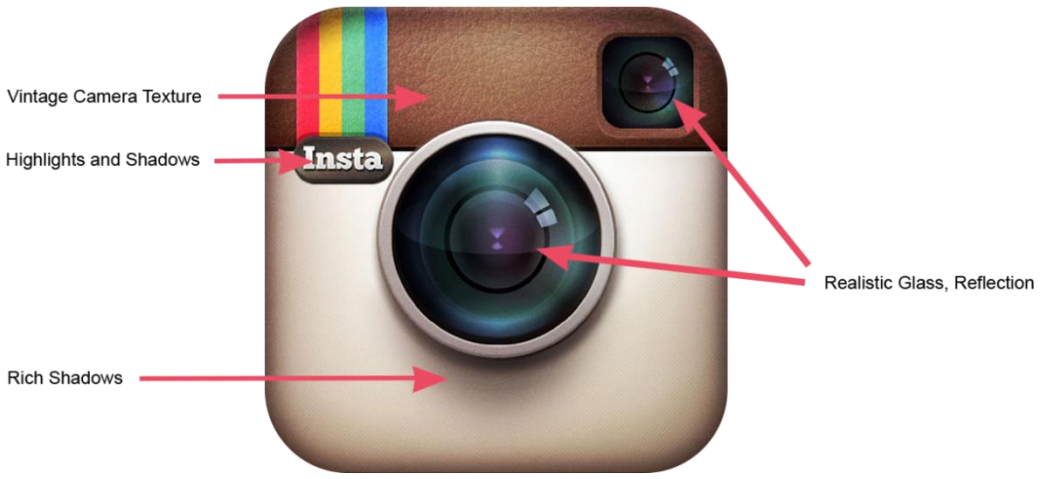


Figure 3.7 Example of skeuomorphic details of Instagram's original logo (Smith, 2016)

Trend of skeuomorphic design consists of use of textures, shadows, reflections, etc. in order to imitate real physical objects. In other words skeuomorphism aims to benefit from previous experience of users about physical life in order to enable them to interpret new graphical interfaces easily, and improve their performance.

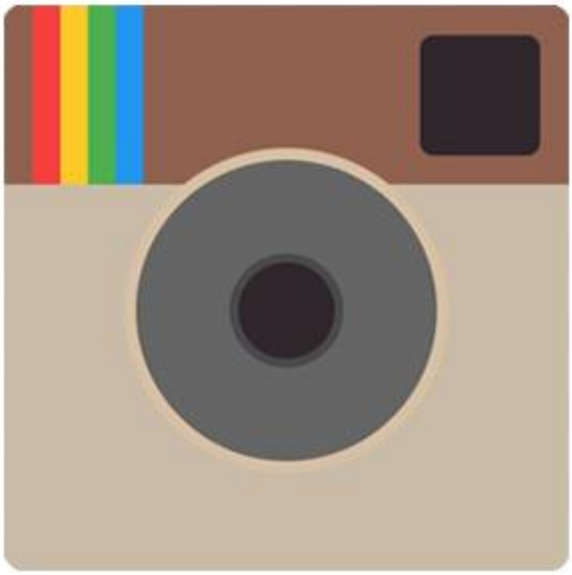


Figure 3.8 Example of flat design of Instagram's icon (Smith, 2016)

Although, the examples of skeuomorphic icons look more satisfactory compared to flat ones, Rybarczyk, Coelho, Cardoso, De Oliveira's (2014) research revealed that flat design obtains better results compared to skeuomorphic design in terms of usability, so metaphors of physical world would not support digital world that much, and skeuomorphism cannot benefit from familiarity of users as it as expected. Also, Spiliotopoulos, Rigo and Sirmakessis (2018) stated that age of users might be an important factor in terms of usability test because older users who do not have adequate experience with digital world might not give effective performance with flat design, so skeuomorphism would help them to interpret

graphical interface better by benefitting from their previous knowledge about physical life. However, trend of flat design would be much more popular in the future thanks to potential user group of digital medium. However, some unsuccessful examples of flat design which is too abstract to be understood easily might cause that user cannot be distinguish them and interpret its function easily, so still there are many people who advocate skeuomorphism against this situation. Thus, flat design should not be considered as designing minimal icons as much as possible instead of designing icon for improving usability by enabling users to intuitive interaction.

3.6 Evolution of Icons

The concept of icon use has emerged quite later than invention computer. With the commercialization of the computer, user interaction came into prominence. As a result of that instead of written descriptions, the icon use has emerged as an important visual element of graphical user interfaces. The early stage of icon use, display and visualization technologies may have affected design trends of icons. Thus, first examples of icon designs were not colorful and they looked quite flat, but they created today's metaphors which are used in all graphical user interface.

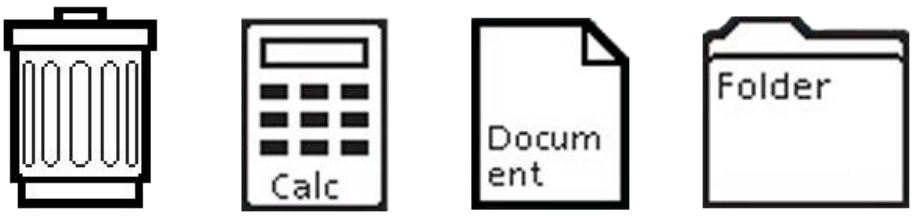


Figure 3.9 The first examples of icons from 1980s (historyoficons, 2015)

These icons were designed for the world's first computer which has a mouse based GUI produced by Xerox. The, Steve Jobs hired the designers of Xerox and developed the world's first personal computer 'Lisa'.

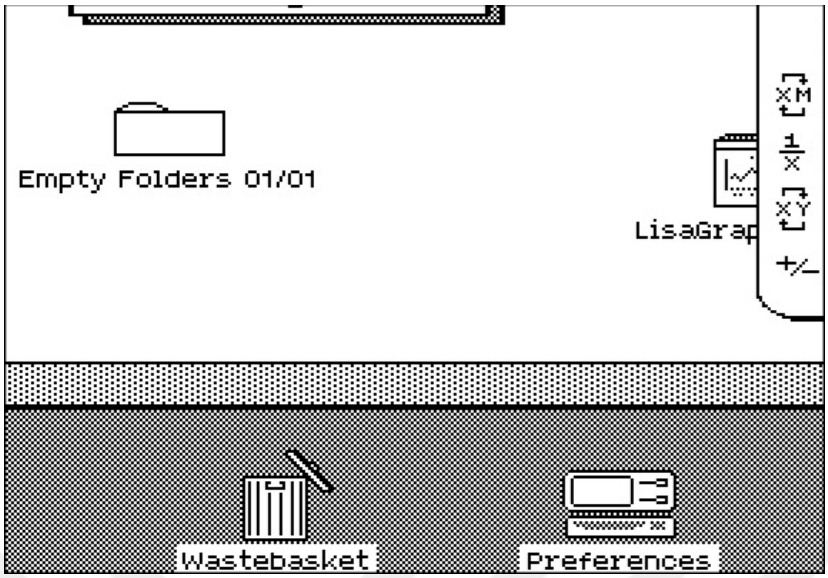


Figure 3.10. A screenshot from Lisa's desktop GUI elements (historyoficons, 2015)

Perkins, Keller and Ludolph (1997) stated that Lisa was designed for office workers, so its graphical user interface imitated their office desks in order to enable easy use by benefitting from their experience with physical environment. Thus, its desktop included folders, basket, calculator, etc. similar to office workers' real desks, so it might be the first example of skeuomorphic approach of Apple. After that, Apple focus on design of icons more and they created new icons with better pixel rates, and Macintosh has announced in 1984 with the first example of look and feel in graphical user interface which refers visual elements and their usability.

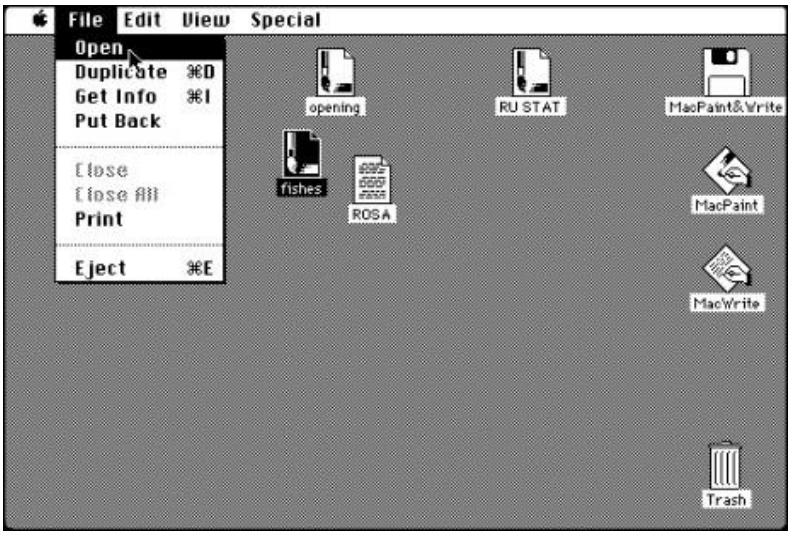


Figure 3.11 The desktop of Macintosh (historyoficons, 2015)

Perkins, Keller and Ludolph (1997) stated that Lisa was designed for office workers, so its graphical user interface imitated their office desks in order to enable easy use by benefitting from their experience with physical environment. Thus, its desktop included folders, basket, calculator, etc. similar to office workers' real desks, so it might be the first example of skeuomorphic approach of Apple. After that, Apple focus on design of icons more and they created new icons with better pixel rates, and Macintosh has announced in 1984 with the first example of look and feel in graphical user interface which refers visual elements and their usability. In 1985, Atari has announced their new computer which is TOS, and also, a new icon trend was announced at the same time because they designed volumetric icons by using lines. Thus, it would be the first example of 3D icon design.

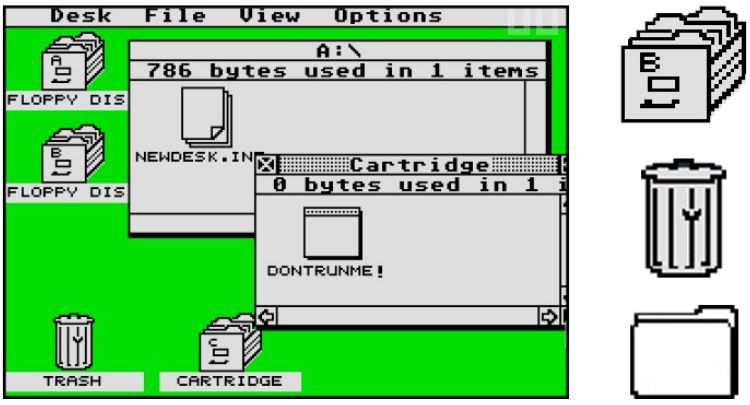


Figure 3.12 The desktop and new icon style of Atari TOS (historyoficons, 2015)

Within the same year, Amiga, US based computer company, announced the first colorful icon designs, but they consisted of maximum of four colors. Amiga's new GUI enabled users to change icons color and sizes for customization.

Figure 3.13 The desktop and new icon style of Amiga (historyoficons, 2015)

After that, Apple also announced a new GUI that enables users to choose colors of icons from 15 determined colors. However, new icon style of Nextstep, software company founded by Steve Jobs, can be considered as a milestone for icon design

because these new icons looked more detailed and realistic than ever before, so it showed the new challenge for icon designs and leaded to rise of skeuomorphism.

Figure 3.14 The desktop and new icon style of Nextstep (historyoficons, 2015)

In the 90s, realism came into prominence for icon design. Also, use of colors and shadows became more popular to improve sense of 3D thanks to improvements in display and visualization technologies. Microsoft's operation system Windows 3, announced in 1990, used color and shadow together for the first time even it was restricted with 16 colors. In this new style, shadow was used to give 3D feeling to icons by providing an isometric view.

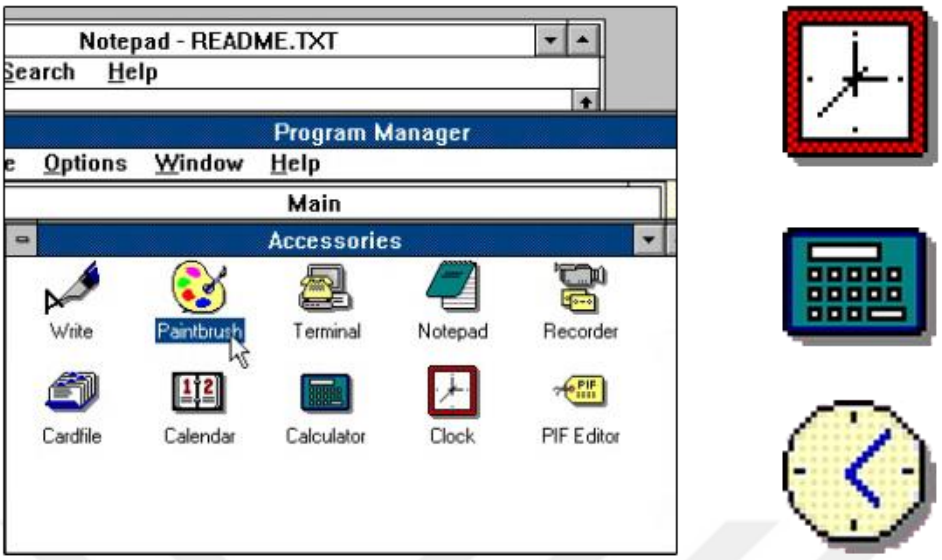


Figure 3.15. Microsoft Windows 3 use of new desktop icon styles (historyoficons, 2015)

Similar to Windows 3, Macintosh 7 operation system tried to create a sense of 3D for its icon design, but instead of using shadow and side view of icons, it had inner shadows and gray-scale gradients.

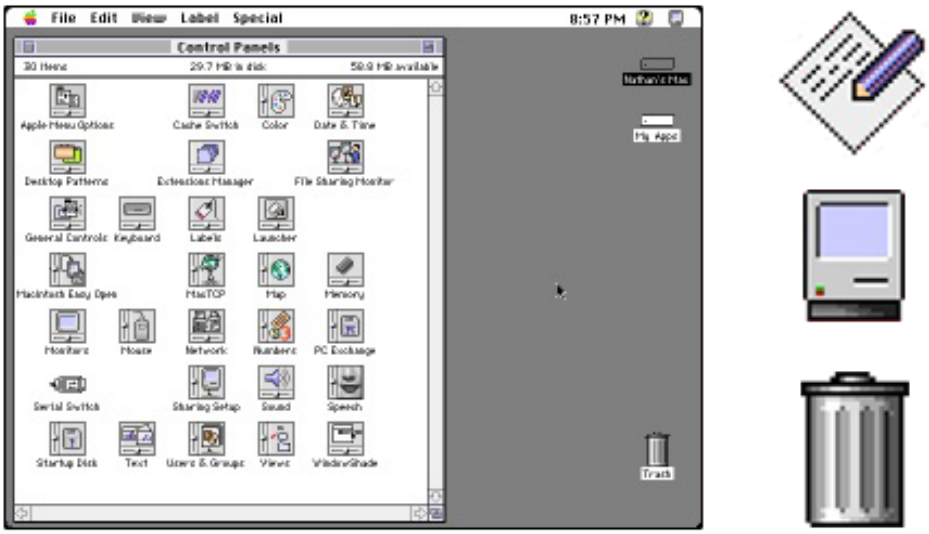


Figure 3.16 The desktop and new icon style of Macintosh 7 (historyoficons, 2015)

In 1997, BEOS, operating system developed by Be Inc, succeeded in providing a quite successful sense of 3D compared to technology at that time by changing the viewing angle of the icons and it carried the trends of 3D icon design one step further by changing viewing angle with colors and shadows.

Figure 3.17 The desktop and new icon style of BEOS (historyoficons, 2015)

Besides that, IRIX's, desktop environment developed by Silicon Graphics, new icon style brought two important improvements although they do not look as good as BEOS's icons. First of them is that they announced the first vector icons. Second, they raised the icons from ground a little bit besides isometric view, so it helped to improve sense of 3D with a shadow effect.

Figure 3.18 The desktop and new icon style of IRIX (historyoficons, 2015)

In 1999, RHAPSODY used transparency mask in order to improve sense of 3D by simulating light reflections with inner shadows according to viewing angle, so icon designs came closer to realistic skeuomorphic types.

Figure 3.19 The desktop and new icon style of RHAPSODY (historyoficons, 2015)

Technological improvements and new visualization technics led icons to look realistic as much as possible in order to benefit users' previous experience with physical objects and adopt their real knowledge to virtual world via graphical user interfaces. In 2000's, new visual effects were added to icons to carry their reality one step further by giving the sense of material via multi layers and masks. Mac OS X might be defined as the first representative of this new trend. They looked successful at giving sense of material via reflective surface and looked realistic without strict borderlines.

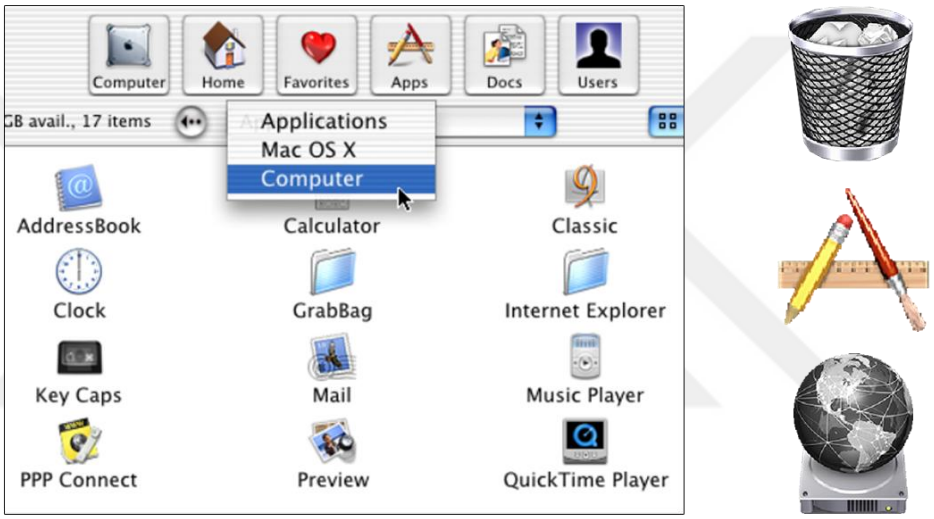


Figure 3.20 The desktop and new icon style of MAC OS X (historyoficons, 2015)

After that Windows XP was announced, but its icons included multi layers less than MAC OS X although it was the representative of same 3D icon trend. However, these icons were revised with Windows Vista by adding new layers to improve effects of materials via reflective surfaces.

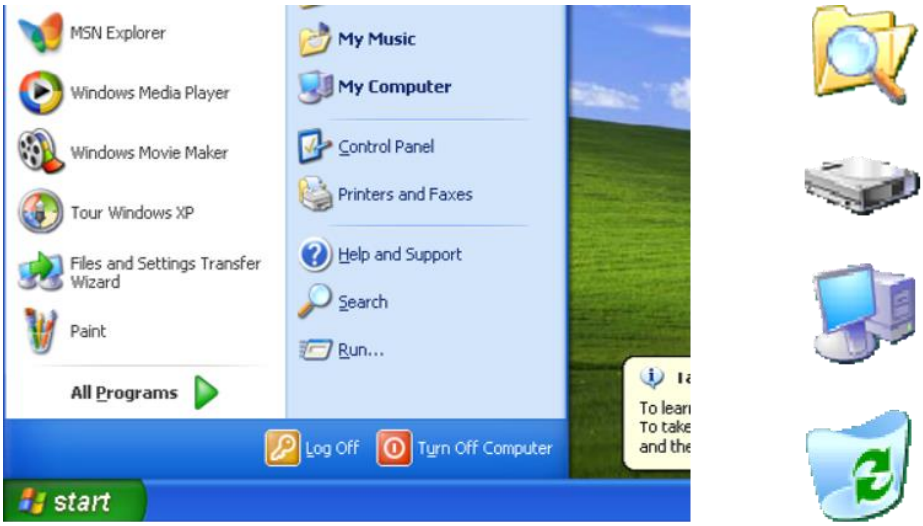


Figure 3.21 The part of desktop and new icon style of Windows XP (historyoficons, 2015)

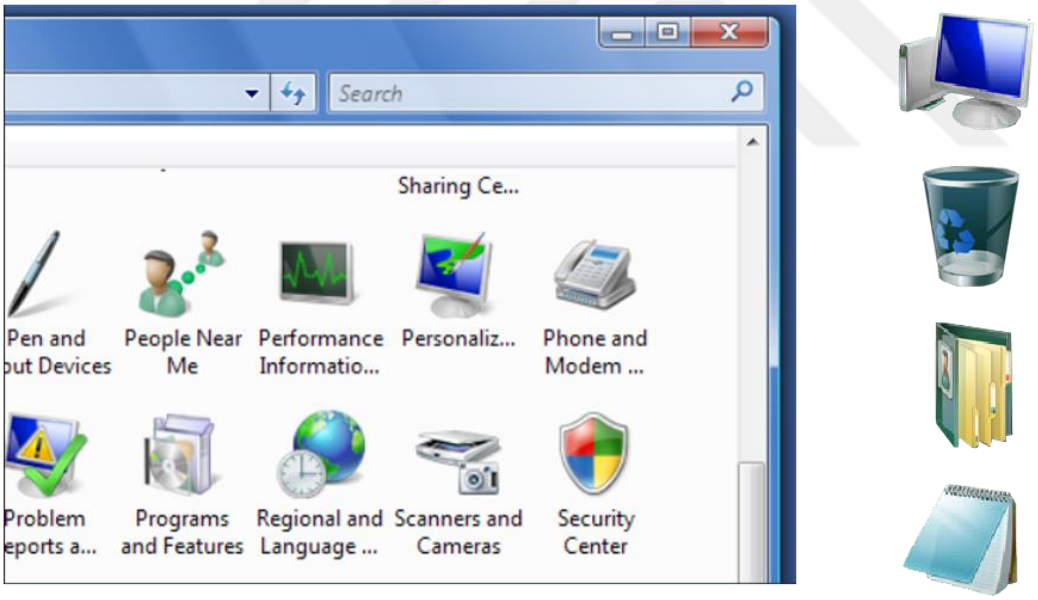


Figure 3.22 The screenshot of a part of desktop and new icon style of Windows VİSTA (historyoficons, 2015)

Icon use and their production has gained importance with the spread of smartphones, but the first examples of IOS and Android which are the most famous operating systems included skeuomorphic icons, so there were a lot of effort to reproduce the real world in order to improve users' performance by benefitting from their experience with physical objects.

Figure 3.23 The GUI and new icon style of Iphone OS (2007) (historyoficons, 2015)

Figure 3.24 The GUI and new icon style of Android (2008) (historyoficons, 2015)

The early examples of icon design show that there was a race of creating realistic icons by reproducing real world in order to show users familiar environment to provide better performance. Companies tried different methods from trying to provide a sense of 3D with different angles, shades and shadows, to using multi layers and to transparency masks in order to obtain more realistic-looking icons. However, digital environment provides different interactions from real life, so it should have its own language that does not reflect real world directly.

In this point, trying to reproduce real life by imitating physical objects might not always help to improve users' performance by imitating their previous experience, so it is not necessary to use excessive details on icons design to create realistic look. After the 'realism trend', all the visual effects that were used to make icons more realistic has become out of fashion in the 2010s, and icons returned their own simple forms in order to make their meanings focal point. Microsoft has showed the first examples of this trend in GUI of Windows Phone with its new flat design. In fact, Microsoft has announced new icons which have simple shape without any visual effects, and they were colorless, so they do not look 3D anymore.

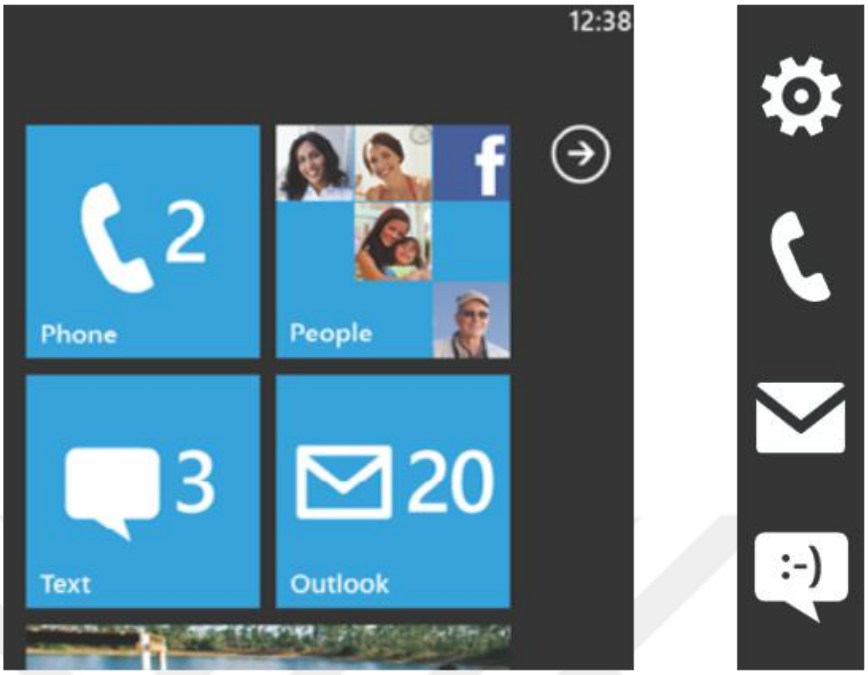


Figure 3.25 The GUI and new icon style of Widows Phone 7 (historyoficons, 2015)

After a long race to reach realistic icons, Microsoft has announced new icons which have simple shape without any visual effects, and they were colorless, so they do not look 3D anymore. With new design trend, most of applications and software started to use flat icons. Also, colorful versions of flat icons appear, but the effects of shadows and multi layers are quite low compared to previous examples.

Figure 3.26 The examples of colorful flat icons (historyoficons, 2015)

3.7 Comparison of Design Trends

The skeuomorphism was the first well-known design trend which represent real world in GUI. In fact, the evolution of icons reveals the effort of designers to emulate visual elements to real world objects by using shadows, gradients, layer, etc. The main aim of this trend was providing users similar environment in order to benefits from their previous experience with real life to provide easy use via predictable interactions. However, it became clear that the digital world is different from real world with the increased interaction of people with digital devices. For example, the "Notes" application of Apple looked like a real notebook which even includes lines on page that completely useless for digital interfaces. Thus, a new trend which is flat design emerged to serve the needs of the digital world to avoid conflict which visual metaphors cause.

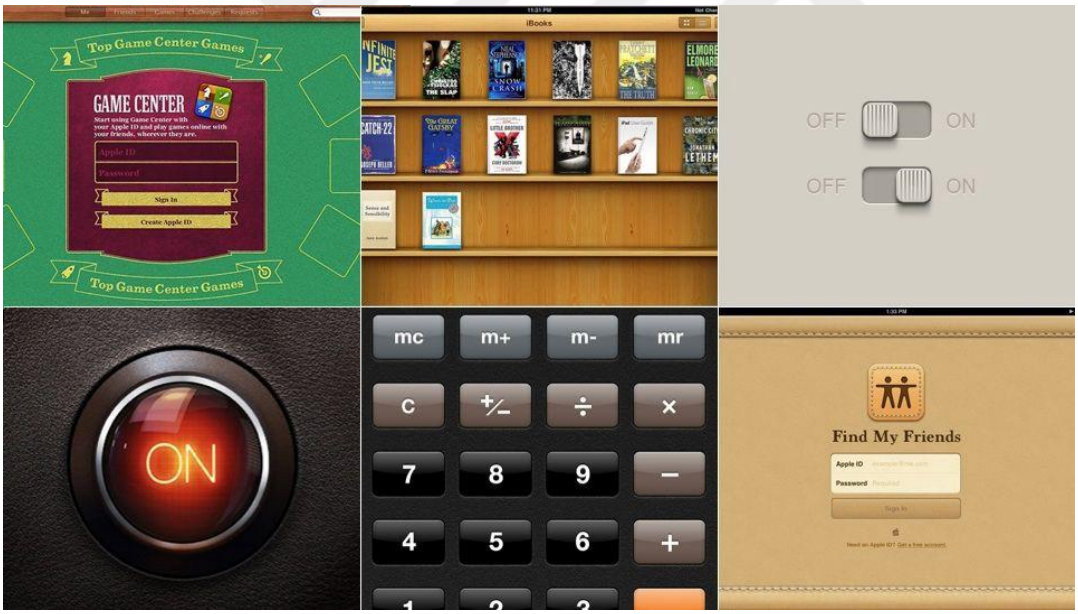


Figure 3.27 The examples of skeuomorphic visual elements (Designwonderful, n.d.)

Flat design focused on functionality of visual elements in terms of conveying their meanings without using visual metaphors in order to make icons look super realistic. Thus, it is a more minimalist trend which includes only simple shapes,

colors and typography compared to skeuomorphism. As a result of that, flat design provides much more clear interface by getting rid of excessive use of graphical details in order to mimic real life objects. Also, increased use of icons in flat design needs less space that written descriptions, so it provides more functional interface in terms of directing users without crowded visuals. With the elimination of unnecessary visual details, icons and buttons become more dominant in flat design in terms of visual hierarchy, so they do not include shadows, gradients and extra layers mostly, and using simple geometric shapes and colors for buttons and icons are usually sufficient. However, use of colors is crucial for flat design in terms of creating correct visual hierarchy in order to make users understand meaning of colors on interface easily. Thus, colors should be bright enough in order to provide better contrast with other different elements and background color. Also, consistency in color selections is crucial to direct users for better interaction. For example, all buttons on interface should have same colors, and there should be a specific color code for warning on the interface in order to make users understand the function of these colors on interface easily. As a result of this minimal structure, lack of excessive use of visual elements would help users to find what they need on the screen fast and easily without fewer distractions. Thus, users would not be overburdened with excessive visual information and options, and also, colored buttons and icons catch users' eyes easily in clear interface that supports such visual hierarchy. Apart from that, adaptation of flat design in different screen sizes is much easier than skeuomorphic design because it consists of geometric shapes and they are not affected by distortions that much during resizing. Also, design of flat icons is easier for designers compared to skeuomorphism because they do not have to make effort in order to imitate real world objects.

Figure 3.28 The examples of flat visual elements (99designs, 2016)

However, users who are not familiar with flat design may have difficulties while understanding the meaning of visual elements because of lack of metaphors. Thus, icons should be used for only familiar iconic expressions, and if there is a need of a new icon design, it should be tested with a lot of users in order to be sure that it will be understood easily. Google, US based technology company, has announced its own design guideline which is trend of "material design" that designed in order to satisfy need of similar presentation of GUI for different screen sizes for different Android devices. Although it looks similar to trend of flat design, it has small differences that would make important impacts. The main differences between flat and material design is that shadows and motions are used to mimic physical world in order to increase to predictability by benefit from user experiences with real world in order to eliminate the main disadvantage of flat design that it might be difficult to be used and understood by users who are not familiar with digital world and its interactions. Thus, although material design is a minimal trend similar to

flat design, it aims to use effect of depth by using shadow in order to provide more predictable hierarchy and interactions, so it would be defined as a combination of digital and real world. Moreover, adding such real world effects to interface with material design helps users to distinguish buttons and interactions easily compared to flat design because it would be difficult to understand different layers, buttons, etc. in flat design for crowded screen, but using effect of depth with shadows solve this problem in material design. In fact, material design aims to make users more familiar with digital world experience by benefiting from their real world experience, but different from skeuomorphism, it does not aim to make all elements look super realistic.

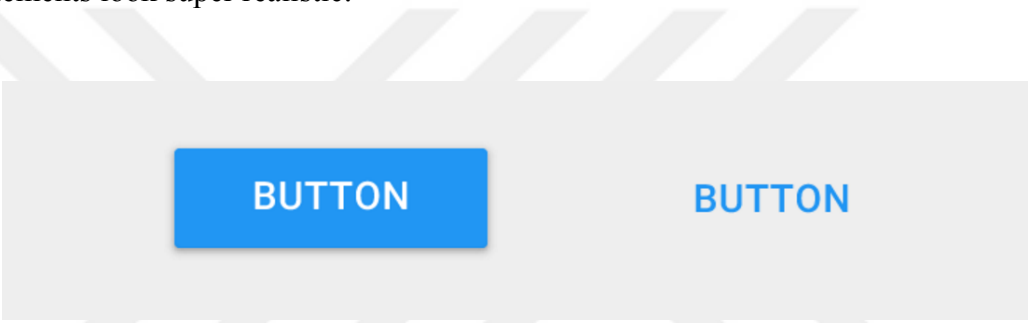


Figure 3.29 The difference between flat and material design (99designs, 2016)

Although visual elements of material design do not look like super realistic with different visual effects like reflections, outer glow, inner shadow, etc. unlike skeuomorphism, it includes small realistic touches like shadow and color system in order to differentiate some elements like buttons to guide users better and provide more familiar interactions. For example, Figure 28 shows that using different color and shadows for button design creates feeling of real push-button for users, so it would make interface more intuitive and user friendly.

Figure 3.30 The example of material design (99designs, 2016)

In conclusion, the first well-known design trend which is skeuomorphism can be defined as an imitation of real world in order to offer interfaces that users would feel more familiar thanks to their previous experiences in real life. After that, flat design occurred as a reaction to skeuomorphism by eliminating unnecessary visual details which are used to make interface more realistic in order to focus on function and performance with minimal interfaces. Also, it would be used in different screen sizes thanks to its easier adaptation compared to skeuomorphism. However, eliminating visual metaphors in flat design makes users' performance rely on their previous experience with similar digital interactions, so it would be difficult to be used by users who are not familiar with digital world. Thus, Google created trend of material design in order to provide more intuitive interface by combining skeuomorphism and flat design. Thus, adapting some visual details that would remind users to interactions from real world would make interface more predictable and familiar in terms of interaction.

3.8 The effects of color use on GUI

The use of color in GUI design is crucial in terms of guiding users by creating consistent visual hierarchy for better experience. In fact, using eye-catching colors for specific elements like buttons would make them more distinguishable for users at first glance, so such dominant elements in visual hierarchy would be so effective in terms of directing users. As Johnson (2013) said that contrast is a crucial point for such dominant elements, so contrast between background color and visual elements like buttons, icons, etc. would determine their visual dominance in the screen. Moreover, there are several studies which research users' performance and preferences for different foreground background color combinations for visual elements in order to provide beneficial guidelines for that. Also, White (1990) and Fowler and Stanwick (1995) stated that amount of contrast between foreground and background is the key point for legibility, so color combinations should be determinant according to that for better user experience. White (1990) and Fowler and Stanwick (1995) investigate the contrast differences by converting alternative colors to grayscale in Photoshop, and then, they controlled values of gray between foreground and background. Moreover, gray values range from 0 for black to 255 for white, so they defined difference in gray values up to 85 as worst, and over 170 as a best in terms of legibility.

Key: Best Worst

Foreground Color

Background Color

	Black	Blue	Green	Cyan	Red	Magenta	Brown	Lt Gray	Dk Gray	Lt Blue	Lt Green	Lt Cyan	Lt Red	Lt Magenta	Lt Brown	White
Black	0	15	75	90	38	53	113	192	128	29	150	179	76	105	226	255
Blue	15	0	60	75	23	38	98	177	113	14	135	164	61	90	211	240
Green	75	60	0	15	37	22	38	117	53	46	75	104	1	30	151	180
Cyan	90	75	15	0	52	37	23	102	38	61	60	89	14	15	136	165
Red	38	23	37	52	0	15	75	154	90	9	112	141	38	67	188	217
Magenta	53	38	22	37	15	0	60	139	75	24	97	126	23	52	173	202
Brown	113	98	38	23	75	60	0	79	15	84	37	66	37	8	113	142
Lt Gray	192	177	117	102	154	139	79	0	64	163	42	13	116	87	34	63
Dk Gray	128	113	53	38	90	75	15	64	0	99	22	51	52	23	98	127
Lt Blue	29	14	46	61	9	24	84	163	99	0	121	150	47	76	197	226
Lt Green	150	135	75	60	112	97	37	42	22	121	0	29	74	45	78	105
Lt Cyan	179	164	104	89	141	126	66	13	51	150	29	0	103	74	47	76
Lt Red	76	61	1	14	38	23	37	116	52	47	74	103	0	29	150	179
Lt Magenta	105	90	30	15	67	52	8	87	23	76	45	74	29	0	121	150
Yellow	226	211	151	136	188	173	113	34	98	197	76	47	150	121	0	29
White	255	240	180	165	217	202	142	63	127	226	105	76	179	150	29	0

Figure 3.31 The amount of contrast between foreground and background color (Tullis, 1997)

Besides legibility, use of color in GUI design is also effective in terms of organization of screen design and users' search performance. In fact, graphical user interfaces would include a lot of information, so prioritization of information would be crucial in terms of guiding users. Thus, color can be used in order to improve users visual search performance by differentiating particular information or elements on the screen. For example, using specific color for indicating state of the system in GUI would this information distinguishable for users on the screen, so it would also affect their reaction time and performance positively by making them realize critical changes about status of system instantly. However, such color coding for grouping in user interface must be used carefully in order to create consistent and logical structure not to confuse users. In fact, same colors should be used for the elements of the same group, and the dominance of the colors on the screen should be determined according to the importance of the information they represent.

3.9 Studies About Effects of Icon Design in GUI

Design trends in graphical user interfaces have started to change with technological developments. Graphical user interface came into existence as an imitation of the real world and it has evolved in order to look more realistic with graphical developments, after that, it has turned into a performance and function oriented approach. For this reason, studies which investigate effect of different designs of users' performance have occurred. For example, Huang's study in 2007 which is "*Effects of computer icons and figure/background area ratios and color combinations on visual search performance on an LCD monitor*" aimed to investigate such effects. In fact, his study is based on examining how the user's selection time varies for different variables by selecting the target icon type among 19 distracters. Also, this study includes three variables which are foreground/background colors consist of black/blue, black/red, black/yellow, white/blue, white/yellow, icon types consist of post, print, email, save, and

figure/background area ratio consists of 50%, 70%, 90%. Thus, as a combination of these variables, there are 60 stimuli in total.

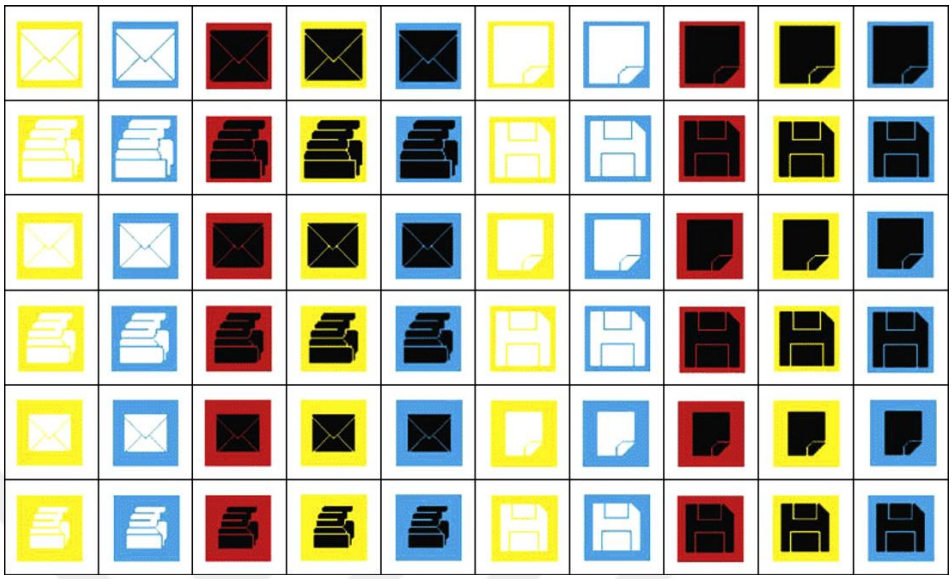


Figure 3.32 The 60 stimuli used in this study (Huang, 2007)

In this study, the software was designed which demonstrate 20 stimuli in circular array randomly for search performance test. Before each demonstration target icon which includes specific icon type, color combination and figure/background ratio is showed for 3 second, and then user is asked to find this target icon from 19 distractors which have same figure/background area ratio as fast as possible and click on it with the cursor of mouse. Also, the software keeps the time in order to compare how fast participant can find the target icon, and these demonstrations are repeated with different target icons 60 times for each participant in order to compare effect of different variables according to search time.

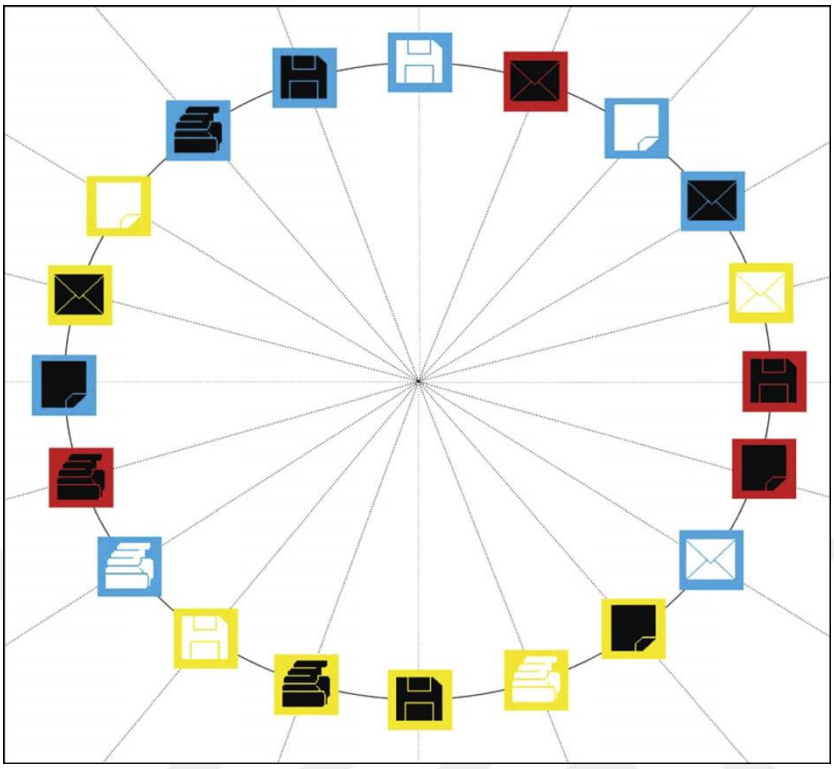


Figure 3.33 The example of demonstration (Huang, 2007)

This study was conducted with 40 participants consist of 20 male and 20 female and aged between 20 and 41 years. Also, results were analyzed with ANOVA, and the results have showed that each variable has an important effect on users' search performance.

According to results, foreground/background color combination has a significant effect on users' search performance because participants perform better while searching black/blue and black/yellow compared to white/blue and white/yellow, so this result reveal the importance of contrast between target and background in search performance. However, although the importance of contrast in order to make target more eye-catching and improve user performance positively is known, colors must be chosen by considering possible eye strain and logical visual hierarchy in graphical user interface design. Thus, it is necessary to examine whether the color combinations determined in this study according to only their contrast values are suitable for use in a real GUI design.

Also, the study showed that icon types have a significant effect on search time because according to results, participants have found "print" icon faster than others. Similarly, contrast of this icon which its complex shape compared to others causes might make it more distinguishable between other distracters. However, these icon types actually have different meanings, so it is not necessary to compare them visually with each other, but if the different designs of the icons with the same meaning would have been compered, it would be more valuable to make a choice between them.

Moreover, results of study showed that participants performed better while finding targets which have 70% figure/background area ratio compared to 90%, and there were no significant difference with 50%, so if the figure is too close to the boundaries of the background shape, it may decrease its distinguishability.

In conclusion it is a valuable study in order to show the effects of icon design on user performance, but it would be more beneficial if the tested variations were designed with more reasonable combinations, and a shorter test could be designed for participants for that they can perform more stable without fatigue during the test without visual comparison of different icon types.

Another important study is the "*Effects of Icon Concreteness and Complexity on Semantic Transparency: Younger vs. Older Users"* which is conducted by Schröder and Ziefle in 2008 in order to investigate the effect on concreteness and complexity of icons which are used in mobile phones on users' performance from different age groups. Thus, the study was conducted with 10 young participants aged between 19 and 29 years, and 10 old participants aged between 50 and 65 years. For this experiment, 12 different functions on mobile phones were determined and 4 different icons that one each abstract simple, abstract complex, concrete simple and concrete complex were used to represent this function. Also, one of these icons was taken from real mobile phone's interface because it might

help to investigate effect of familiarity and age depended performance differences in real interfaces, and other icons were designed to investigate effects of concreteness and complexity. Besides that, a software was developed which would show 4 target and 4 distracter icons subsequently in a trial, and participants ask to decide whether it represent its function as fast as possible by clicking "confirm" or "reject" on the screen in order to measure participants' reaction time and asses their confirmative responses. Also, each demonstration which includes 8 icons was repeater 4 times in order to investigate effect of familiarity, so for 12 functions, participants asses 384 icons in total during the test.

Complete Icon Set of Twelve Target Functions (real icons are grey shaded)

Reference function	Abstract		Concrete	
	Simple	Complex	Simple	Complex
Battery charging level				
Net availability				
Dial tone silent				
Mailbox				
SMS				
Keylock				
Call diversion				
Alarm clock				
Headset				
Appointment				
Vibration				
Camera				

Figure 3.34 The example of icon designs used in study (Schröder&Ziefle, 2008)

As a result of this study, although older participants reacted slower than younger ones, the study has showed that complexity and concreteness of icon design is a crucial for performance of all participants. Also, according to results, complexity of icons increases reaction time of all participants, and concrete icons were confirmed more than 70% while abstract ones were confirmed 40%. Moreover, responses of concrete icons were not affected by repeated trials, so it is obvious that concreteness is a crucial factor for icon design in order to provide better user experience. Also, young and old groups perform same performance at 10 of the 12 functions, and 8 of these functions were concrete and simple icons. Apart from that, icons from real phone's interfaces were usually found as a best for both participant groups.

Reference Function	Icon with Highest Fraction of Confirmative Responses		Reference Function	Icon with Highest Fraction of Confirmative Responses	
	Young Adults	Old Adults		Young Adults	Old Adults
Battery charging level	 100.0%	90.0%	Call diversion	 95.0%	82.5%
Net availability	100.0%	82.5%	Alarm clock	 90.0%	75.0%
Dial tone silent	 95.0%	77.5%	Headset	 57.5%	10.0%
Mailbox	 67,5%	 52.5%	Appointment	 97.5%	87.5%
SMS	 97.5%	95.,0%	Vibration	 90.0%	 82.5%
Keylock	 80.0%	60.0%	Camera	 77.5%	77.5%

Figure 3.35 The icons with the highest Fraction of confirmative responses in each task (Gray shaded icons are from real phone's interface) (Schröder&Ziefle, 2008)

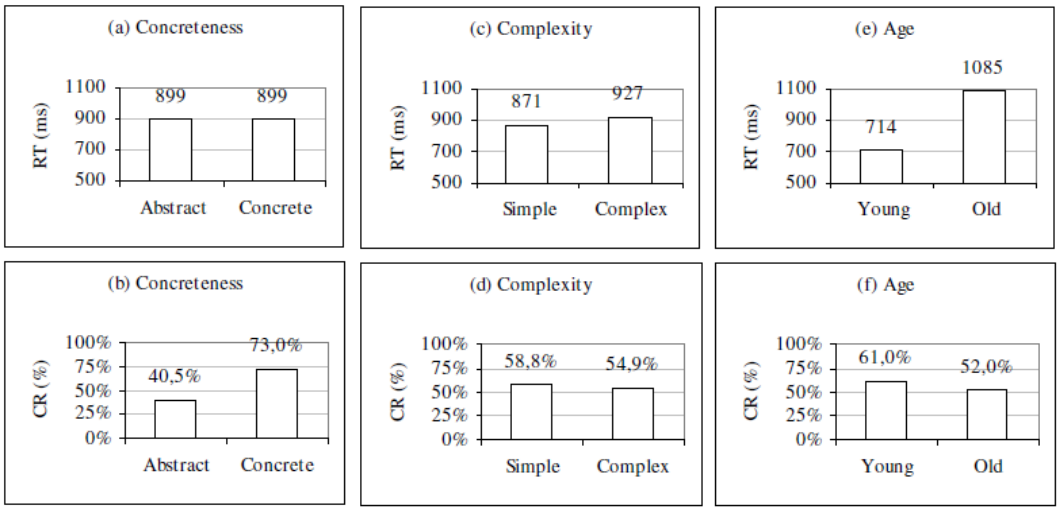


Figure 3.36 The reaction time and confirmative responses for each variable

According to these results, it is obvious that concreteness affects users' reaction time negatively, but familiarity can eliminate this difference. Besides that, age as another variable for this study do not affect general performance although older group has always higher reaction times because it seems that there is no problem about understanding the meaning of icons in interface.

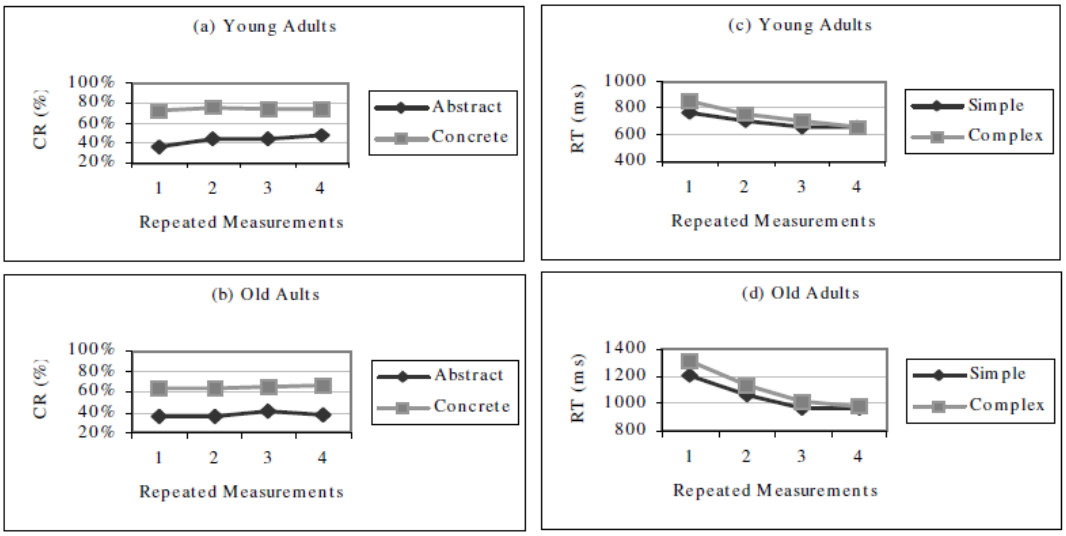


Figure 3.37 Changes in reaction time and confirmative responses after repeated trials (Schröder&Ziefle, 2008)

In conclusion, this study which investigated effect icon concreteness, complexity and age of user on user experience has shown important results. According to result of study, it is obvious that using simple and concrete icon design in GUI design which will be used by users from wide age range would provide better user experience in terms of understanding meaning of buttons intuitively. Also, it has shown that effect of familiarity would eliminate some performance problems about icon complexity, and this is also important result that revealed that complex icons would be use in a graphical user interface which has long-term use scenarios, but using of such icons in interfaces which would have short-term interaction like websites would cause negative effect on first impression of users. The drawbacks about this study would be that the abstract versions of icon designs are too abstract and the number of participants would not be enough to tolerate performance drops in such a long test.

Another study which was conducted by Zhou and Luo, in 2014 is "*Effects of smartphone icon background shapes and figure/background area ratios on visual search performance and user preferences".* In fact, this study was conducted with 40 participants by using 7 background shapes, 5 figure/background area ratio and 3 screen sizes in order to investigate effect of these variables. This test was shown at smartphones, so icons were listed on the screen with 4x5 matrix similar to smartphone interfaces. Also, 10%, 30%, 50%, 70% and 90% as a figure/background ratio, and several geometrical shapes were used as an experimental materials.

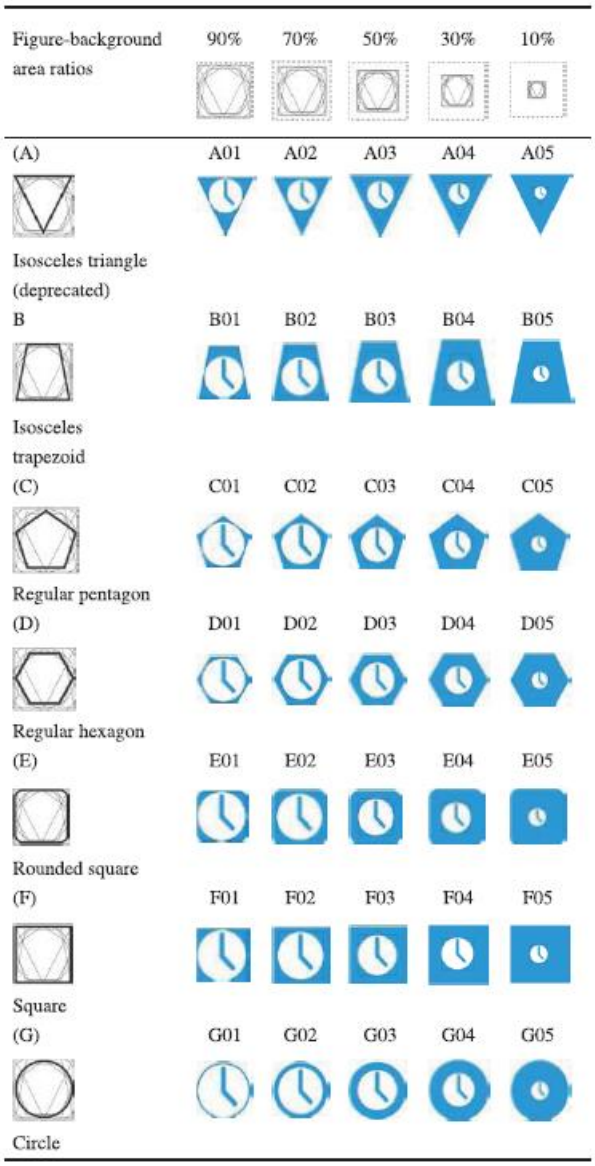


Figure 3.38 The icon designs used in experiment (Luo&Zhou, 2014)

During the experiment, among the 20 icons on the screen, it is requested to find the "clock" icon as soon as possible as a target icon, and this process is repeated 4 times, with the locations of all icons changing randomly. In the meantime, how fast the user finds the target icon is measured in order to investigate effects on their search performance. After testing search performance, participants were asked to evaluate icon designs by giving point from 1 to 7 according to their individual preferences. The result of experiment showed figure/background area ration affects

users' performance, and participants performed better at 70% figure/background/ ratio, and also, 10% is the worst one.

Means and standard error of task completion time (*s*) and icon design preference ($n = 40$)

Screen size	Variables	Task completion time		Icon design preference	
		Mean	Std. Error	Mean	Std. Error
3.5 inch	Background shape				
	B	2.30	0.08	2.43	0.02
	C	2.39	0.08	3.44	0.02
	D	2.60	0.08	3.85	0.02
	E	**1.99**	0.08	**5.89**	0.02
	F	2.02	0.08	5.05	0.02
	G	2.23	0.08	4.74	0.02
	Figure/background area ratio				
	90%	2.30	0.06	3.72	0.02
	70%	**2.12**	0.06	4.06	0.02
	50%	2.14	0.06	**4.33**	0.02
	30%	2.38	0.06	4.28	0.02
	10%	2.83	0.06	2.94	0.02
4.0 inch	Background shape				
	B	2.17	0.06	3.46	0.02
	C	2.23	0.06	3.89	0.02
	D	2.43	0.06	4.02	0.02
	E	**1.48**	0.06	**5.91**	0.02
	F	1.89	0.06	5.15	0.02
	G	2.07	0.06	4.88	0.02
	Figure/background area ratio				
	90%	2.16	0.08	3.77	0.03
	70%	**2.07**	0.08	5.38	0.03
	50%	2.20	0.08	**6.18**	0.03
	30%	2.24	0.08	5.66	0.03
	10%	2.53	0.08	5.39	0.03
4.7 inch	Background shape				
	B	2.21	0.08	3.02	0.02
	C	2.33	0.08	3.47	0.02
	D	2.49	0.08	3.75	0.02
	E	**1.64**	0.08	5.96	0.02
	F	1.97	0.08	5.83	0.02
	G	2.16	0.08	4.78	0.02
	Figure/background area ratio				
	90%	2.34	0.06	2.45	0.02
	70%	**2.13**	0.06	3.42	0.02
	50%	2.26	0.06	4.87	0.02
	30%	2.48	0.06	5.03	0.02
	10%	2.66	0.06	5.51	0.02

Figure 2.39 The results of experiment (Luo&Zhou, 2014)

Moreover, the results showed that background shapes affect users' performance and preferences, but the correlation between user performance and preferences about background shapes is not clear. According to results, participants performed better at background shapes of circle, rectangular and rounded rectangular, and they liked most these shapes.

In conclusion, it is an important study in terms of showing how background shapes and figure/background ratio would affect users' performance and their preferences. However, these results would occurred due to the fact that three background shapes that participants performed better are currently used in digital world, so people interact with them in their daily life, and also, alternative shapes were insufficient and unrealistic. Similarly, 10% or 30% figure/background ratio were not realistic values.

3.10 Conclusions

Technological developments leaded to occurrence of new interactions with everyday products. In fact, with the developments in electronic components of the products, and new functions that it brought cause the occurrence of digital control screens apart from mechanical buttons. Besides that, with the invention of computers, graphical user interfaces have entered our lives. Nowadays, people are surrounded by many things that they interact with via GUI such as computers, smart phones, web pages, online services and applications. Moreover, the digital world has almost replaced real interaction in some areas. However, the first examples of GUI appeared as imitations of the real world. The aim of GUI is enabling users to communicate with device in order to benefit from its function. Thus, similar to physical interfaces, graphical ones have layout, buttons, groups, etc. in order to communicate with users. However, the most important and innovative graphical elements in such interfaces are icons because this pictorial interaction is the best characteristic feature of graphical user interface. Thus,

changes in design of icons can be investigate in order to understand design trends from past to present.

In the first examples of graphical user interface design of icons was developed in order to mimic real world to provide familiar interface for users. Next, icons have evolved super realistic appearance with the technological developments and use of new visual effects like shadows, reflections, transparency, etc. However, widespread use of graphical user interfaces in different devices and areas caused competition in the market, so the concept of performance for graphical user interfaces became the main topic. Thus, interface designs started becoming simpler by focusing on users' performance. As a result of that trends of icon designs that can be adaptable different screen sizes and represent its meaning without causing too much eye strain in order to provide better user experience.

In the first examples of GUI designs and icon designs, the most important and determinative criteria were how they look realistic in order to benefit from users' previous experience to provide them with more intuitive interaction. However, after focusing on how users interact with such graphics well, the effects of characteristics of icons like concreteness, complexity, color, shapes, etc. became focal point for designers and researchers. Thus, many studies have been conducted in order to investigate both effects of characteristic features of icon design like color, shape, size, proportion, etc. on users' search performance by investigating how they understand icons function, and find them easily despite of distracters on the screen and their individual preferences. However, these studies do not go beyond proving the possible effects of characteristic features of icons. In other words, they try to prove effect of variables by comparing them with extreme examples. Thus, comparison between reel alternatives in order to decided which one would be better at real graphical user interface design needs to be made specifically in the light of all these studies in terms of methods and conclusions.

CHAPTER 4

A STUDY OF THE EFFECTS OF ICON DESIGN AND BACKGROUND COLOR ON VISUAL SEARCH PERFORMANCE AND USER PREFERENCES

4.1 Introduction

The researcher's current employment and one of the job definitions, development and testing software interfaces of military system like air surveillance radar systems, sets one of the main motivations for making graphical user interfaces (GUIs) of military systems more user friendly in terms of improving icon design and color usage. For this reason, this study was designed to investigate the effects of icon designs and background colors on users' performance (of completing a certain task). The study also aimed to achieve more realistic and feasible results by adhering to some limitations in military interfaces.

However, the results of this study are believed to be beneficial for other sectors with similar interface design limitations as well. The biggest problem of GUIs of military systems is that they have a lot of critical functions, such as detection, diagnosis of a thread and applying countermeasures. Therefore, these systems usually have very crowded and complicated interface screens to show all the necessary information but at the same time, performance of the operators is crucial as they must not make any mistakes according to Bhattacharyya, Chowdhury, Pal and Majumdar (2014). Such systems should avoid too distracting GUIs in order to not to cause any eye strain and mental fatigue on operators who have to perform for long hours a day. Another important criterion is that the information visualization must be clear to improve (or at least not to decrease) users' performance. According to study of Shen, Zhang, Xiao, Li and Liang (2020) This can be

achieved by paying attention to familiarity and distinguishability of the icons as these would help users (i.e. operators) to easily locate them on the screen

With these in mind, alternative icon designs which will be tested in this study must be simple and minimal like trend of flat design or material design (see in Chapter II). Also, as much as possible concrete icon design need to be chosen to test in this study because this study focuses on distinguishability, so using abstract icons in this study would lead participants to make effort to understand meaning of target icons or distracters. Therefore, concrete icons are preferred to provide them familiar environment. Also, Schröder and Ziefle's (2008) study shows the positive effects of concreteness on users' performance.

Figure 4.1 illustrates an example GUI of a military system. In the example, there are a lot of menus, graphs, settings that operators control during the operation, so visual balance and hierarchy is important in order to guide operator according to order of process. Thus, use of color is also crucial issue for such interfaces in terms of indicating status, situations or messages about the system. As a result of that, color choice for icons that will be tested in this study is also important issue, so colors of icons in such GUIs should not be too distracting. Moreover, red, green and yellow should not be used as an icon color because these colors are commonly used as an indicator of system status. For example, red is used in order to indicate error or thread, yellow is used in order to indicate warning and green is used in order to indicate success or working without problem. Thus, using these colors for icons would cause confusion for the operators.

Additionally, according to Brockmann (1991), using bright colors for other visual elements in GUI would decrease the dominancy of these colors which shows status of system, so it would affect the response time of operators negatively and would cause crucial mistakes for such important military systems during the operation.

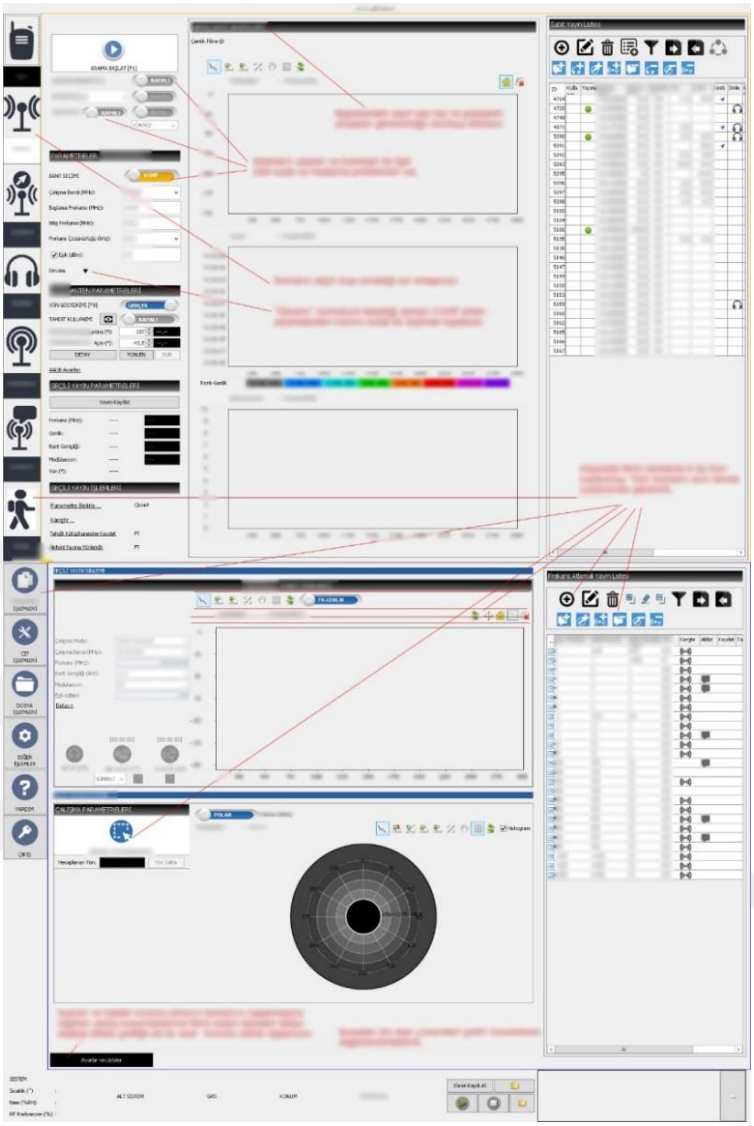


Figure 4.1 The example of a crowded screen-based interface used in a military system by the author

Figure 4.2 shows that red, green and yellow are often used to indicate the system and missions which the operator responsible for. Therefore, using these colors for different visuals would decrease the noticeability of the crucial information on the screen. The figure 3.2 also shows an example of a dark-color-theme used in GUI different from Figure 3.1, and this difference refers to another important criterion for military interfaces.

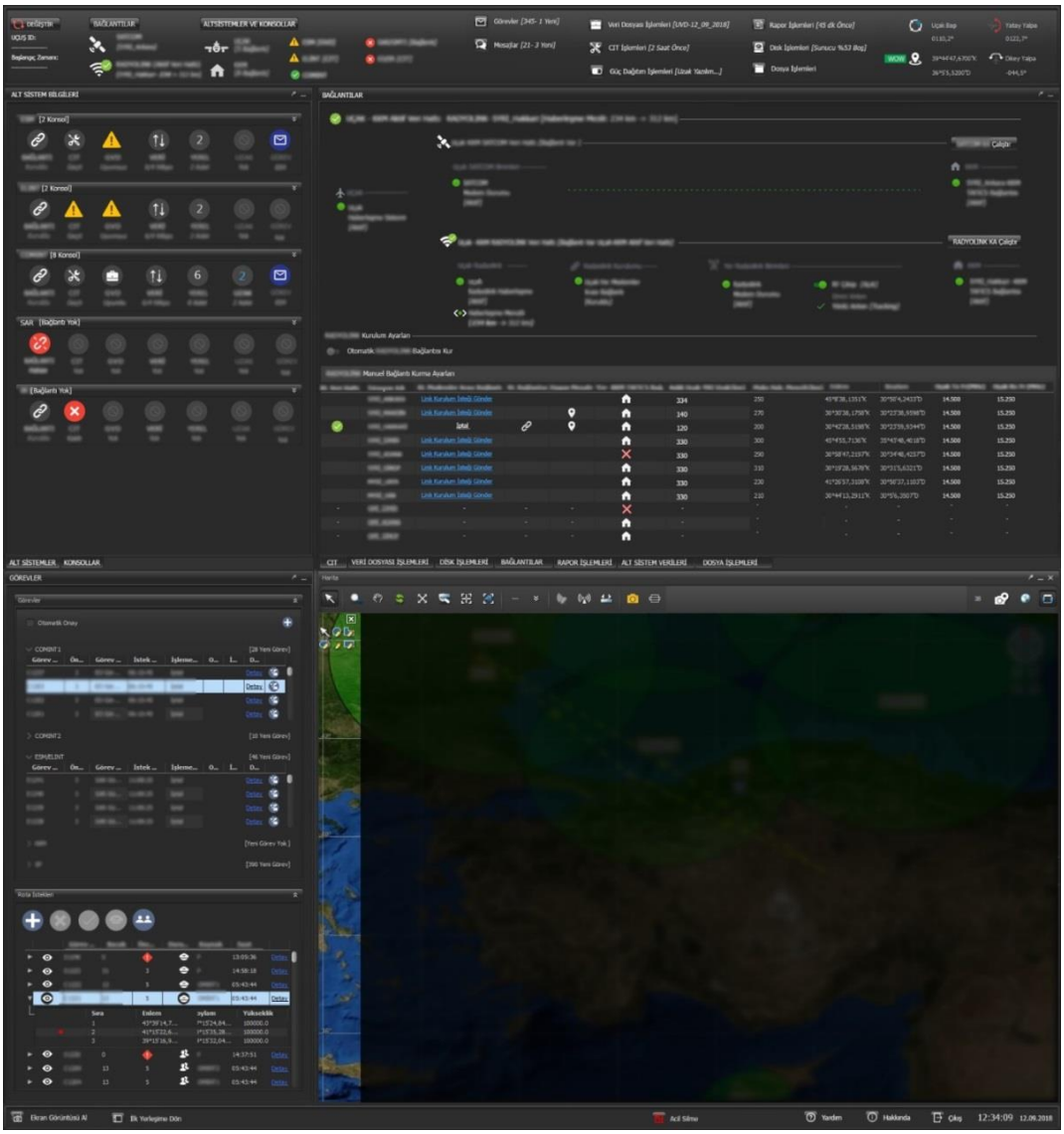


Figure 4.2 The example of a crowded status indicators on the screen by the author

Some of the military systems are used in outdoor during operation, while some are used in dark environment in the shelters, so the use of dark and light themes are necessity for different context to provide good visibility and legibility for the operator during operation,; to prevent the operators from making mistakes; and to not to cause eye fatigue in different environments with different light settings. However, software developers and designers might tend to use the same icon sets on both dark and light theme instead of designing two sets of icon for complex military GUI's, so the icon sets that will be tested in this study aim to provide

enough contrast with both dark and light themes in order to explore whether it is possible to use same icon sets on different background colors.

4.2 Experiment Setup

In order to compare icon sets in terms of users' visual search performance and preference depending on participants' task completion time and subjective ratings, the test software was developed. The test software was designed with Java, programming language, which runs on Windows 10 to store the logs of "task completion time" and "subjective evaluation ratings" for eight design alternatives that include four different icon sets on two different background colors (see section 1.5).

4.3 Selection of the Participants

It was aimed to get wide range of feedback and obtain statistically meaningful data. Therefore, this study was conducted with 83 participants from different age groups. Figure 4.3 shows the distribution of the participants by age groups. Although the effect of users' age on their performance is not the subject of this study, demographic information was collected for further research.

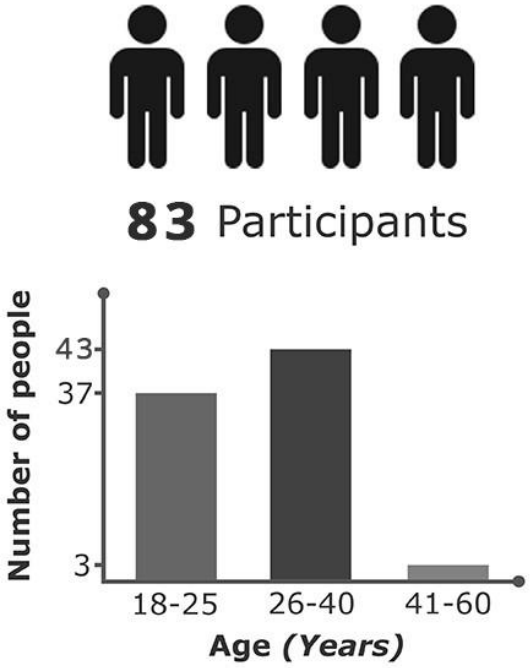


Figure 4.3 The distribution of participants by age groups by the author

It was believed that the reaction time of older people can be longer than the younger participants, it would not have any effect on determining the best icon design because they would react equally slowly for all options, so the total time difference between them will not change in comparison of icons, but nevertheless the age groups of the participants were gathered in order to that they might be used in new version of study in the future. Accordingly, 37 of participants were between18-25, 43 were between 26-40, and were between 41-60 years old.

As the most important criterion, the participants were selected among the experienced users who are using at least two professional CAD programs in order to eliminate negative effect of being unfamiliar with digital world and icon types because slow and inconsistent reaction time of inexperienced users would have manipulated the statistical results. Thus, the study was conducted with participants who are familiar with such GUIs. Moreover, the participants were selected among the engineers working in the defense industry with the aim of working with people similar to the operators in terms of their knowledge about the domain. Also, these

participants who are colleagues of researcher were invited to this study via a general e-mail mentioned briefly about the subject of the study.

4.4 Venue and Equipment

All test sessions were carried out across the computer desk, using a 17-inch monitor with 1080x1920 pixels resolution and mouse from a minimum viewing distance of 70 cm. This was because the GUIs were aimed to be used with same size monitor and mouse in real-life, therefore the results were expected to simulate realistic situation. The sessions were carried out in an office room illuminated with natural light. There were no background reflections on the screen caused by lighting or any distracting objects on the desk. The participants were left alone to not to distract them, and each participant was allowed in the room once the previous one completed.

4.5 Icon Design Sets Used as Test Materials

There are two independent variables which are background color and icon design in this study. The limitations of the many GUIs that this study tries cover were important factors while determining these variables. For example, only black and white background colors were tested by considering day/night modes of GUIs because, almost all GUIs that we interact in daily life include day and night modes, so they consist of similar themes.

There are several criteria for icon designs that will be tested in this study. First of all, familiar icon types were chosen by researcher to manipulate their design during the test. Therefore, participants will be prevented from interpreting the meaning of icons differently within different reaction times. To obtain more realistic reaction times, using more complex or simpler icon types than participants would encounter in GUIs which they interact in their daily life was avoided.

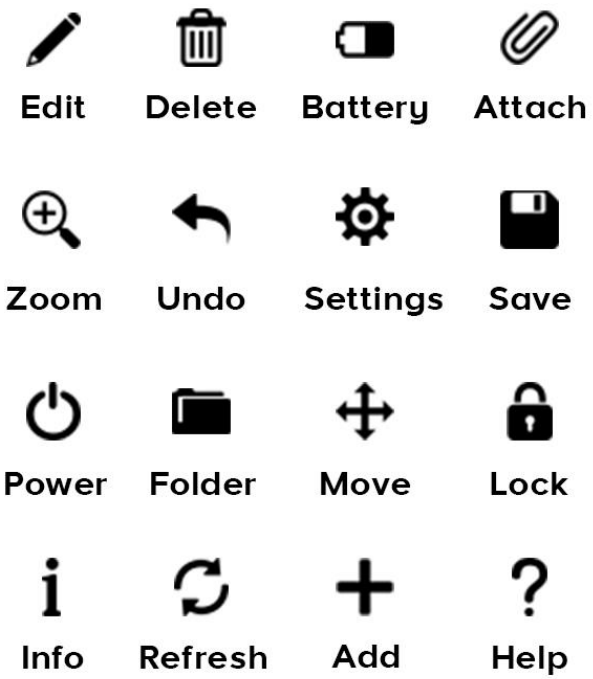


Figure 4.4 The icon types that are used in the study (icon8.com)

Figure 4.4 illustrates all of the icons that will be tested in the study. These are familiar icon types that all participants encounter in their daily life because all participants have experience with professional CAD programs which includes such icon types. Therefore, the visual search test with these icons is expected to give a realistic result. Also, due to common use of flat and material design trends in current operator systems like IOS, Android, Windows, etc., these design trends were followed by researcher while designing icon sets which will be tested in this study because the positive effects of these trends are on users' performance have been revealed in previous studies, so most of current GUIs carry the traces of these trends.

Another crucial criterion for this study is to explore whether it is possible to use the same icon set for both dark and light themes in GUI. Therefore, each icon set that will be tested must provide a certain amount of contrast with black and white background because White (1990), and Fowler and Stanwick (1995) revealed in

their study that amount of contrast between foreground and background is crucial in terms of legibility. In their study, alternative colors were converted to grayscale in Photoshop, and they measured the value of gray between foreground and background. As a result, gray values range from 0 for black to 255 for white, so they defined difference in gray values up to 85 as worst, and over 170 as a best in terms of legibility. Thus, while designing alternative icon sets that will be tested in this study, these values were considered for the best visibility of icons on dark and white themes. However, there are other limitations regarding the general use of color in military systems in color selection. For example, some colors like red, orange, yellow, and green are used in status notifications related to the system or task status in GUIs, so the use of such colors in icon design can cause serious confusion. In addition, the use of feminine colors such as pink and purple will not be very suitable because of the product semantics.

Figure 4.5 The first icon set - 1 that will be tested in the study

The first icon set was designed simple in order to match the flat design trend, and also, while choosing gray color, it was paid attention to find color between black and white which would provide sufficient visibility on both themes.

Figure 4.6 The contrast ratio of Icon set-1 (WebAIM, 2020)

According to standards of WCAG (Web Content Accessibility Guidelines) graphical components should provide at least 3:1 contrast ratio, so it seems insufficient a bit on white background.

Figure 4.7 The icon set - 2 that will be tested in the study by the author

Similar to the first set, the second set was designed simple according to flat design trend. Also, white color and black strokes were used as color choices, so this set will look like an icon design consisting of only black frames on a white background, while it will look completely white on a black background. Thus, it is expected to achieve maximum harmony with both themes because it has 21.0:1 contrast ratio for both theme

Figure 4.8 The icon set - 3 that will be tested in the study by the author

The third icon set was designed as a blue version of the first icon set. This blue color comes into prominence with its high contrast with both themes and the fact that it does not cause any confusion with the colors which are used in order to indicate system status.

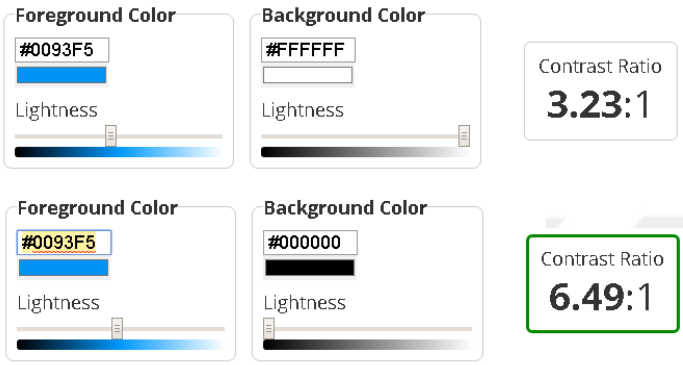


Figure 4.9 The contrast ratio of Icon set-3 (WebAIM, 2020)

According to standards of WCAG, this color provides enough contrast for both white and black although it looks better on black.

Figure 4.10 The icon set - 4 that will be tested in the study by the author

The fourth icon set was designed with a background to create a layer in order to increase feeling of buttons on the screen in accordance with the material design trend. The blue color of background was chosen for the same reasons with the third icon set. Different from the third one, a faded shade of blue was chosen in order to reduce its eye-catchiness that its wide surface area with background causes. Also, its background shape and figure/background ratio were designed according to Zhou and Luo's (2014) study which revealed that rounded rectangular and 70% figure/background ratio provide the best search time for users.

Figure 4.11 The contrast ratio of Icon set-4 (WebAIM, 2020)

According to standards of WCAG, icon set-4 provides the most balanced contrast ratio on both black and white background compared to other alternatives.

4.6 Data Collection Tools

The task completion time were gathered in order to assess visual search performance of participants. Apart from that, subjective evaluation of participants was gathered through the 5-point Likert scale in order to be able to rank icon sets on two backgrounds according to participants' subjective likes. As a result of that numerical information would be analyzed with two-way analysis of variance (ANOVA) to obtain statistical results.

4.7 Procedure

Before starting the test session, participants signed a consent form (Appendix A) which mentioned the purpose of the study and stated that only their performance logs would be evaluated statistically without using their personal information.

Then, the test software started with an information page which explains the procedure that participants will follow during the test in order to make whole process clear for them to obtain their best performance for realistic results.

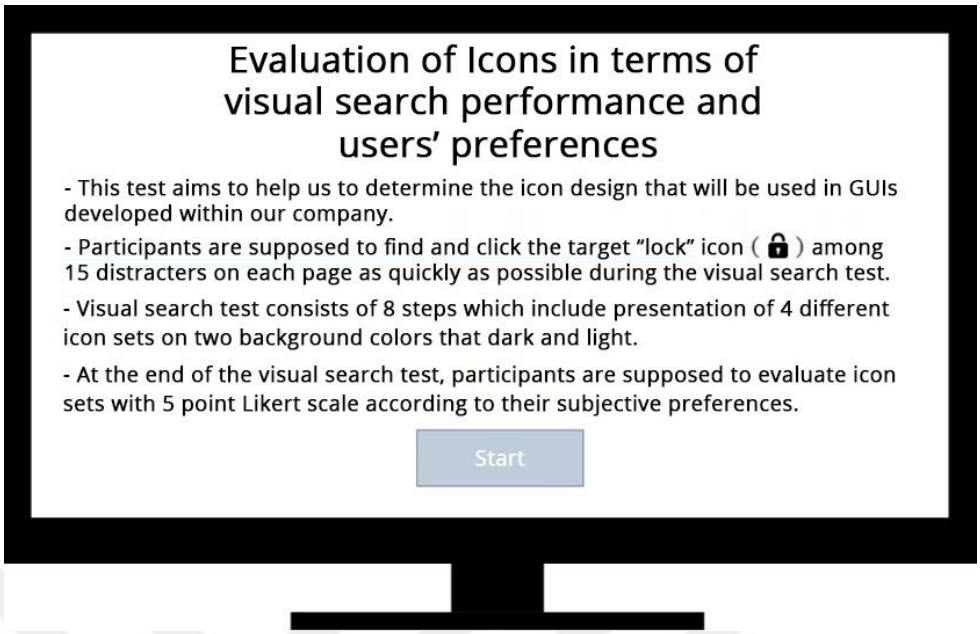


Figure 4.12 The information page of the test software by the author

This information page inform participants about that the visual search test will be shown eight times for four different icon sets on two different background color, and participants will try to choose icon of lock for each showing as fast as possible. Also, at the end of the test, users will rate each showing according to their subjective evaluation. As a result of that, the test results will be used to determine the icon design which can be used in the GUIs developed in the company that the study is conducted with. After reading all information, participants can start the by clicking "start" button on the screen.

Participants search for the find target icon in a circle stimulus array which has a diameter of 16 cm and includes one target and fifteen distracters, and this procedure is repeated eight times for each alternative during the visual search test. The purpose of the circular array is that the cursor is always positioned in the middle in order to be provided equal distance to all icons, so it would provide more realistic results while selecting icons in terms of task completion time. While creating this circular array, Lindberg and Nasanen (2003) study about effect of

spacing on users' performance which revealed that icons should not positioned near to each other without any spacing, and at least ½ icon width space should be used for each icon according to screen size was utilized. Also, icons size was chosen as 32x32 pixels similar to their actual size used in GUIs of the company. Moreover, Lindberg and Nasanen (2003) study revealed that minimum size of icons should be at least 0.9cm according to 70cm viewing distance.

After clicking the button of start on information page, participants will face with a new screen which indicates that the number of next showing for visual search test.

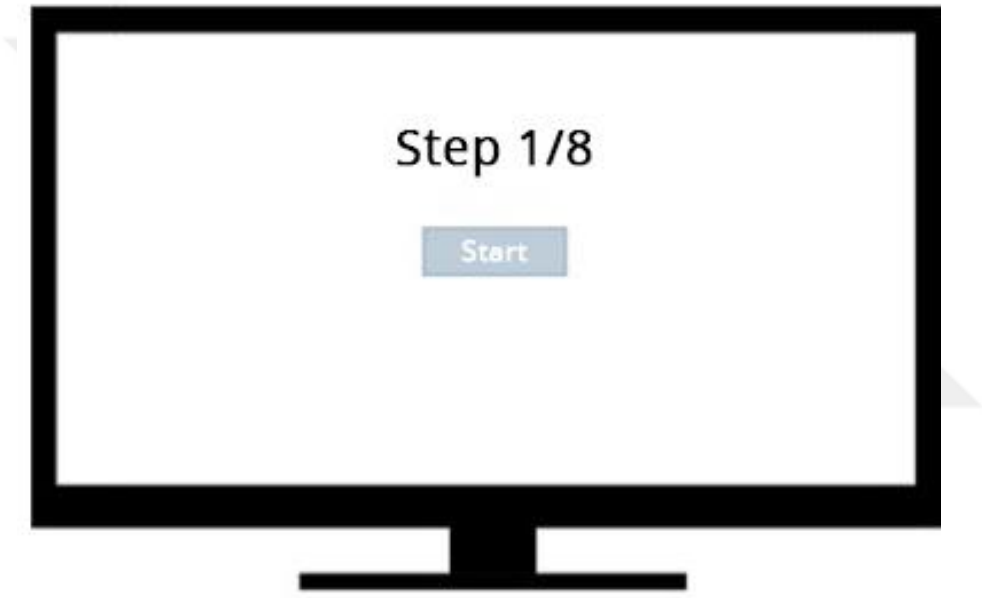


Figure 4.13 The screen which shows the number of next showing by the author

Participants can start visual search test by clicking this button of star at the middle of the screen before each showing. However, the main purpose of this page is that cursor would be located at the middle of screen in order to have equal distance to each icon on circular array after clicking the buttons of start on this page apart from inform participants about order of the visual search test. Moreover, the time logs for task completion start to be taken with the selection of the "start button".

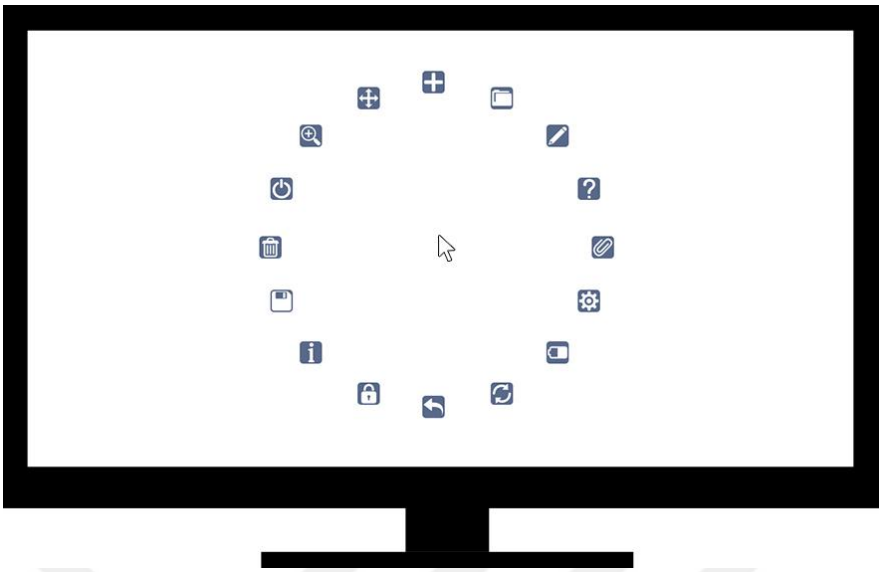


Figure 4.14 The example of a visual search page for an icon set by the author

As the figure 4.14 shows, the mouse cursor should be located at the middle of circular array after clicking the button of start on previous page, so cursor has equal distance to each icon in order to provide better comparison in terms of task completion time of each icon set. Participants search for finding and click on the icon of lock between distractors in order to see next showing with new icon set and background color, and this process is repeated eight times for each alternative which includes four icon sets on two background colors.

Target icon is always the icon of lock for each showing because overall design of icon sets is one of variable of this study, not the icon types. If the target icon would change for each showing, comparison of icon types will be a crucial factor in terms of visual distinctiveness while assessing task completion time, so a reasonable analysis would not be possible with three independent variables such as icon type, icon design and background color. However, if the whole test would be repeated 16 times for making each icons target, reasonable results would be obtained, but comparison of icon types was not the subject of this study. The reason of choosing icon of lock as a target icon is that its form includes both straight and curved lines, and also, its form is complex a bit compared to others, so it would be more

distinctive which help participants not to make mistake while selecting it among distracters.

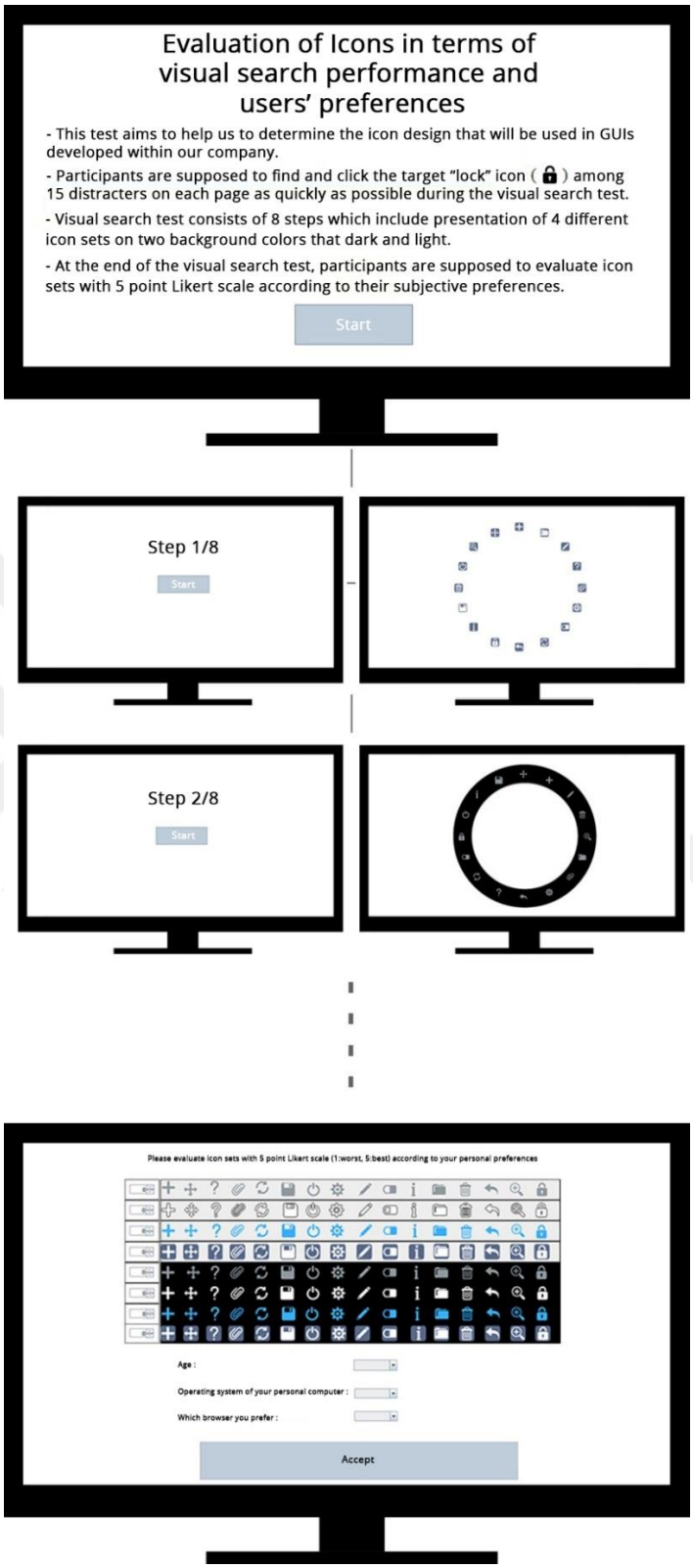


Figure 4.15 The presentation of each steps of the test by the author

During the test, eight alternatives which are four icon sets on two backgrounds were presented in a random order as show as seen in Figure 3.15. Moreover, the location of the target icon and distracters were also randomized in circular stimulus array in order to prevent target icon from being located on certain position for certain icon sets not to manipulate the results because the distracters which were located next to the target would manipulate the result by making visual search process harder or easier according to their similarity with the target.

In fact, target icon would look like more distinctive between the distracters which have completely different forms in terms of their silhouettes while the target would look invisible between the distractors which have similar forms with the target, so if the location of distracters and target icon would not be randomized, task completion times would be misleading for certain icon sets due to these reasons.

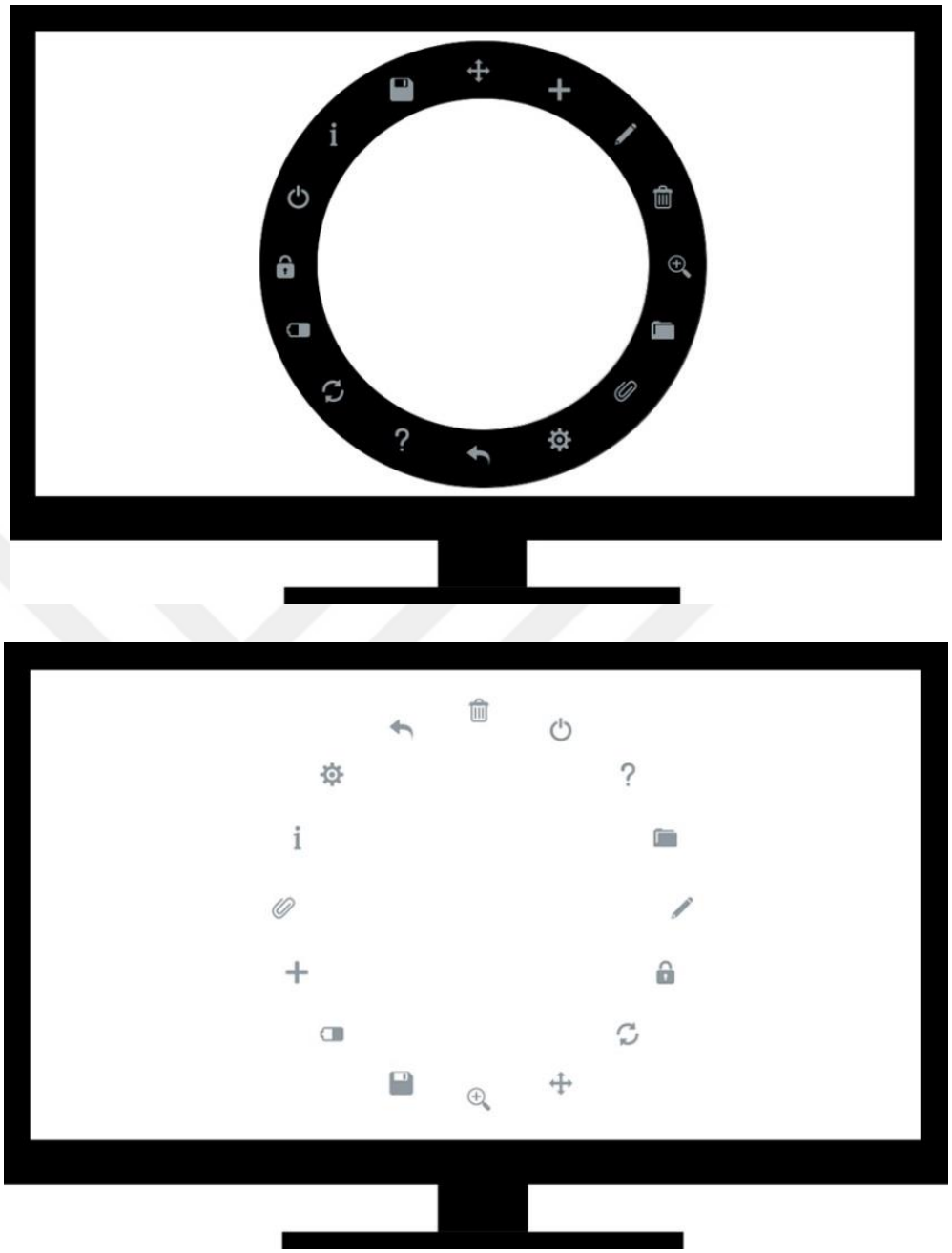


Figure 4.16 The presentation of an icon set on black and white background by the author

In order to assess participants' visual search performance for an icon set on both black and white background, background of the circular array was colorized as seen in figure 49 for the presentation of dark theme.

After completing eight steps for visual search test by selecting icon of lock as fast as possible among four different icon sets that have different design styles on two different background, participants were asked to evaluate eight alternatives through 5-point Likert scales (Appendix B) in order to understand whether there is a correlation between their performance and subjective evaluation, so they can rate the options which they like the most by giving 5 points and the worst by 1 point.

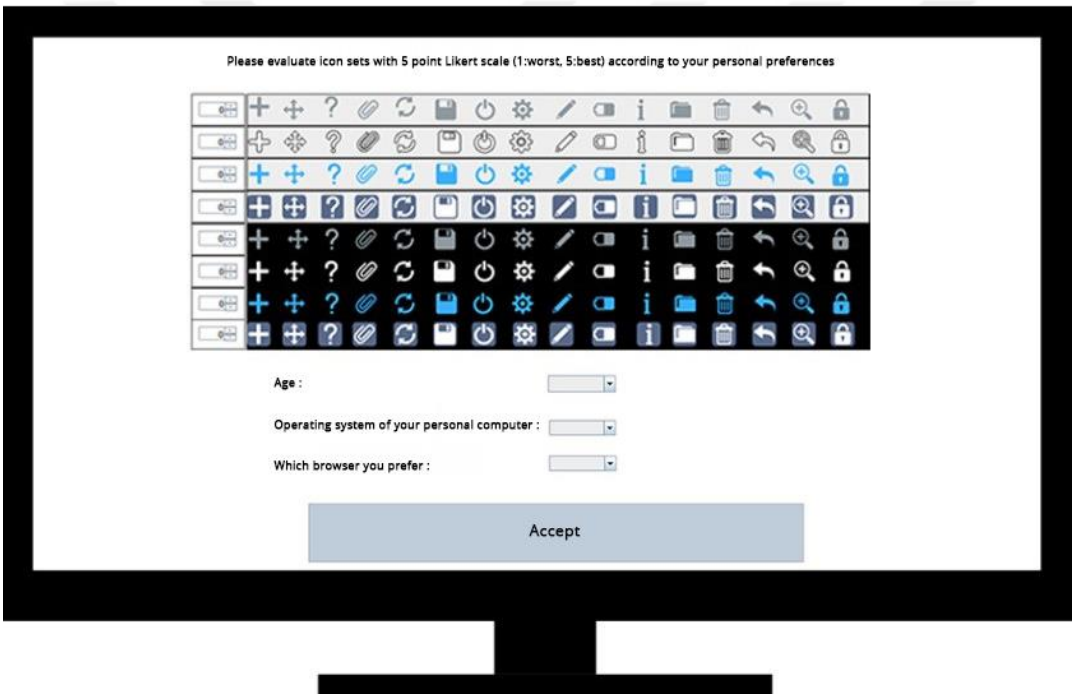


Figure 4.17 The subjective evaluation page of the test by the author

As seen in figure 4.17, participants' commonly used operating systems, web browser and their demographic information were also collected. This information was not the subjective of this study, but these were collected in order to be used for further research. For example, issues such as effect of age on users' visual search

performance or correlation between their internet browser preferences and the effect of GUI design on that can be investigated in the future.

The summary of procedure;

- The test start with an information page explaining the procedure and asking participants to click the target "lock" icon on each page as fast as possible.
- For visual search test, eight alternatives include four icon sets on two background are represented in a random order. Therefore, participants search for the target icon in a circle stimulus array which had a diameter of 16cm and includes one target and 15 distracters. Also, the location of the target icon and distracters is randomized in the circle stimulus array. This procedure is repeated eight times during visual search test for each participant. During this test, time logs of task completion starts to be taken the selection of the "start button" placed in the middle of the screen before each step to prevent the divergence of cursor travel distance.
- At the end of the visual search test, participants are asked to evaluate eight alternatives through 5-point Likert scale according to their subjective preferences. Also, their operation system, web browser and demographic information are collected for further research.

This procedure was repeated for each participant. Also, test process per participant took around 4 minutes averagely, and all tests were completed within 2 weeks.

4.8 Results and Analysis of Visual Search Performance

The logs of task completion time and subjective evaluation ratings were collected via test software. After that, these results were analyzed statistically with SPSS (Statistical Package for the Social Sciences) in order to reveal the effects of variables in the study in terms of users' performance and preferences. There were 3 variables which include in this study;

- **Dependent variable :** Task completion time
- **Independent variables :** Icon design (4 different icon set) and background theme (Black and White)

Thus, the effects of variable icon designs with variable background colors on task completion time statistically, and comparison of icon designs with each other were investigated.

TCT

Descriptive Statistics

Icon	Background	Mean	Std. Deviation	N
Icon Set 1	Light	2,82459	1,408143	83
	Dark	2,59617	1,012343	83
	Total	2,71038	1,227950	166
Icon Set 2	Light	3,07758	1,396658	83
	Dark	2,71917	1,475196	83
	Total	2,89837	1,443341	166
Icon Set 3	Light	3,07600	2,109795	83
	Dark	2,96735	1,432597	83
	Total	3,02167	1,798623	166
Icon Set 4	Light	3,37411	1,985505	83
	Dark	3,11940	1,574261	83
	Total	3,24675	1,790845	166
Total	Light	3,08807	1,758352	332
	Dark	2,85052	1,399106	332
	Total	2,96930	1,592159	664

Figure 4.18 The table of task completion time according to icon sets

As seen in Figure 4.18, participants performed best with icon set 1 (2,59617 second), and worst with icon set 4 (3,11940 second) on dark theme. Also, although there were quite similar results on light theme, icon set 3 turned out better than icon

set 2 compared to dark theme. As a result, it is clear that icon design affects the participants task completion time.

TCT

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	35,876[a]	7	5,125	2,044	,048	,021
Intercept	5854,298	1	5854,298	2334,871	,000	,781
Icon	25,198	3	8,399	3,350	,019	,015
Background	9,367	1	9,367	3,736	,054	,006
Icon * Background	1,311	3	,437	,174	,914	,001
Error	1644,810	656	2,507			
Total	7534,984	664				
Corrected Total	1680,686	663				

a. R Squared = ,021 (Adjusted R Squared = ,011)

Figure 4.19 The interaction between variables

Moreover, figure 4.19 shows that icon design has statistically significant effect on task completion time, $F(7,83) = 3.3350$, $p < 05$,

- Icon set 1 (M=2.71) < Icon set 4 (M=3.24)
- Icon set 2 (M=2.90) < Icon set 4 (M=3.24)

However, there is no significant interaction between icon and background theme, $F(7,83) = ,174$, $p > 05$, . Also, background theme has not a statistically significant effect on task completion time, $F(7,83) = 3.736$, $p > 05$, .

TCT

Pairwise Comparisons

(I) Icon	(J) Icon	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Icon Set 1	Icon Set 2	-,188	,174	,280	-,529	,153
	Icon Set 3	-,311	,174	,074	-,653	,030
	Icon Set 4	-,536*	,174	,002	-,878	-,195
Icon Set 2	Icon Set 1	,188	,174	,280	-,153	,529
	Icon Set 3	-,123	,174	,478	-,465	,218
	Icon Set 4	-,348*	,174	,045	-,690	-,007
Icon Set 3	Icon Set 1	,311	,174	,074	-,030	,653
	Icon Set 2	,123	,174	,478	-,218	,465
	Icon Set 4	-,225	,174	,196	-,566	,116
Icon Set 4	Icon Set 1	,536*	,174	,002	,195	,878
	Icon Set 2	,348*	,174	,045	,007	,690
	Icon Set 3	,225	,174	,196	-,116	,566

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Least Significant Difference

Figure 4.20 The comparison of icon sets in terms of significant differences

The comparison of icon sets in terms of significant differences revealed that icon set 4 is significantly different from icon set 1 and icon set 2 in terms of task completion time. Also, although icon designs affect task completion time, there are no significant differences between others.

TCT

Pairwise Comparisons

(I) Background	(J) Background	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Light	Dark	,238	,123	,054	-,004	,479
Dark	Light	-,238	,123	,054	-,479	,004

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference

Figure 4.21 The comparison of background in terms of significant differences

Moreover, the comparison of background in terms of task completion time revealed that there is no significant difference between light and dark theme although results showed that the participants performed better with dark theme than light theme. According to results in figure 4.22;

- Dark background (M=2.85) < Light background (M=3.09)

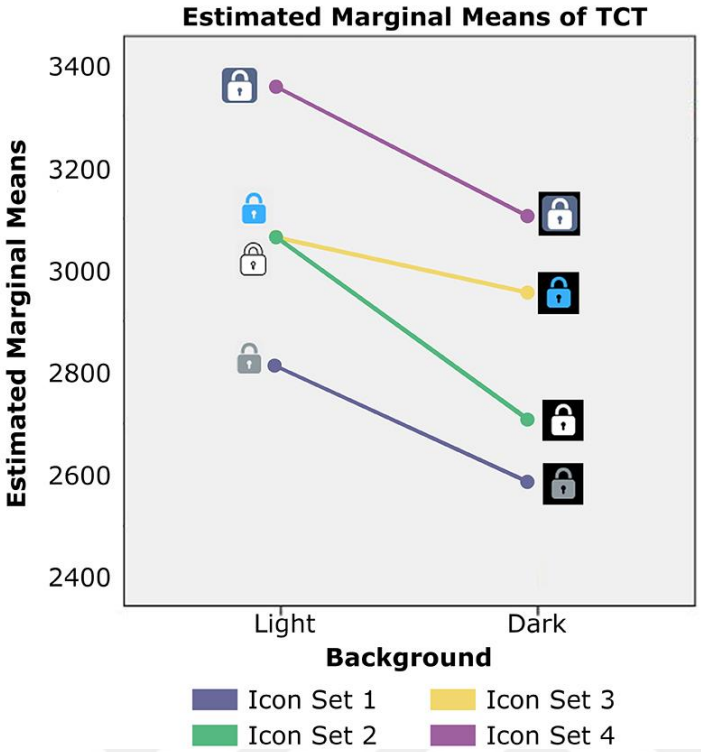


Figure 4.22 The performance of icon sets on two backgrounds

In conclusion, results of the visual search test revealed that icon design could affect task completion time significantly, and also, there were significant differences between some icon sets. Moreover, visual search test of icon sets on different background showed that there were no significant differences for users' performance on different background although they performed slightly better on dark background than light one. Also, results showed that participants performed better with icon set 1 and 2 in total.

4.9 Results and Analysis of Users' Preferences

The logs of participants' subjective evaluation ratings were analyzed statistically with SPSS (Statistical Package for the Social Sciences) similar to logs of task completion time in order to understand the effects icon design and background

color on users' preferences. Also, the correlation between participants' search performance and their preferences was investigated. Similar to analysis of visual search performance, there are 3 variables for analysis of their preferences;

- **Dependent variable :** Task completion time
- **Independent variables :** Icon design (4 different icon set) and background theme (Black and White)

Preference — Descriptive Statistics

Icon	Background	Mean	Std. Deviation	N
Icon Set 1	Light	2,29	1,293	83
	Dark	2,33	1,201	83
	Total	2,31	1,244	166
Icon Set 2	Light	3,08	1,299	83
	Dark	3,54	1,328	83
	Total	3,31	1,330	166
Icon Set 3	Light	2,49	1,272	83
	Dark	3,69	1,104	83
	Total	3,09	1,329	166
Icon Set 4	Light	2,87	1,421	83
	Dark	2,77	1,400	83
	Total	2,82	1,407	166
Total	Light	2,68	1,353	332
	Dark	3,08	1,376	332
	Total	2,88	1,378	664

Figure 4.23 The subjective evaluation ratings according to icon sets

As seen in figure 4.23, the most preferred alternative is icon set 2 (3,31 points in total) and the least preferred one is icon set 1 (2,31 points in total). Also, the highest rated option is icon set 3 on dark theme while the lowest one is icon set 1 on light background.

Preference — Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	161,753[a]	7	23,108	13,817	,000	,128
Intercept	5517,163	1	5517,163	3298,979	,000	,834
Icon	93,572	3	31,191	18,650	,000	,079
Background	26,241	1	26,241	15,691	,000	,023
Icon * Background	41,940	3	13,980	8,359	,000	,037
Error	1097,084	656	1,672			
Total	6776,000	664				
Corrected Total	1258,837	663				

a. R Squared = ,128 (Adjusted R Squared = ,119)

Figure 4.24 The interaction between variables

As seen in figure 4.24, in terms of participants' preferences, there is statistically significant interaction between icon design and background theme, $F(7,83) = 8.36$, $p < 05$, according to h2, 4% of the variance in evaluation ratings is explained by the interaction of icon design and background theme. For example, there is an obvious interaction between background and participants' preferences at icon set 3 case which participants preferred icon set 3 on dark background (M=3.69) much more than light background (M=2.49) . On the other hand, icon set 4 has a negative effect at icon set 4 case which is participants' preferred icon set 4 on light theme (M=2.87) slightly more than on dark them (M=2.77) .

Preference — Pairwise Comparisons

(I) Background	(J) Background	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Light	Dark	-,398*	,100	,000	-,595	-,201
Dark	Light	,398*	,100	,000	,201	,595

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Least Significant Difference

Figure 4.25 The comparison of background in terms of significant differences

Also, background theme has statistically significant effect on participants' preferences, $F(7,83) = 15.69$, $p < 05$;

- Light background (M=2.68) < Dark background (M=3.08)

Preference

Pairwise Comparisons

(I) Icon	(J) Icon	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Icon Set 1	Icon Set 2	-1,006*	,142	,000	-1,285	-,727
	Icon Set 3	-,783*	,142	,000	-1,062	-,504
	Icon Set 4	-,512*	,142	,000	-,791	-,233
Icon Set 2	Icon Set 1	1,006*	,142	,000	,727	1,285
	Icon Set 3	,223	,142	,117	-,056	,502
	Icon Set 4	,494*	,142	,001	,215	,773
Icon Set 3	Icon Set 1	,783*	,142	,000	,504	1,062
	Icon Set 2	-,223	,142	,117	-,502	,056
	Icon Set 4	,271	,142	,057	-,008	,550
Icon Set 4	Icon Set 1	,512*	,142	,000	,233	,791
	Icon Set 2	-,494*	,142	,001	-,773	-,215
	Icon Set 3	-,271	,142	,057	-,550	,008

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Least Significant Difference

Figure 4.26 The comparison of icon sets in terms of significant differences

As seen in figure 4.27, comparison of icon sets in terms of their total ratings on both themes, there is a significant effect on users' preferences, $F(7,83) = 18.65$, $p <$ 05, , and also there is a significant difference some icon sets;

- Icon set 1 (M=2.30) < Icon set 2 (M=3.31)
- Icon set 1 (M=2.30) < Icon set 3 (M=3.09)
- Icon set 1 (M=2.30) < Icon set 4 (M=2.82)
- Icon set 4 (M=2.82) < Icon set 2 (M=3.31)

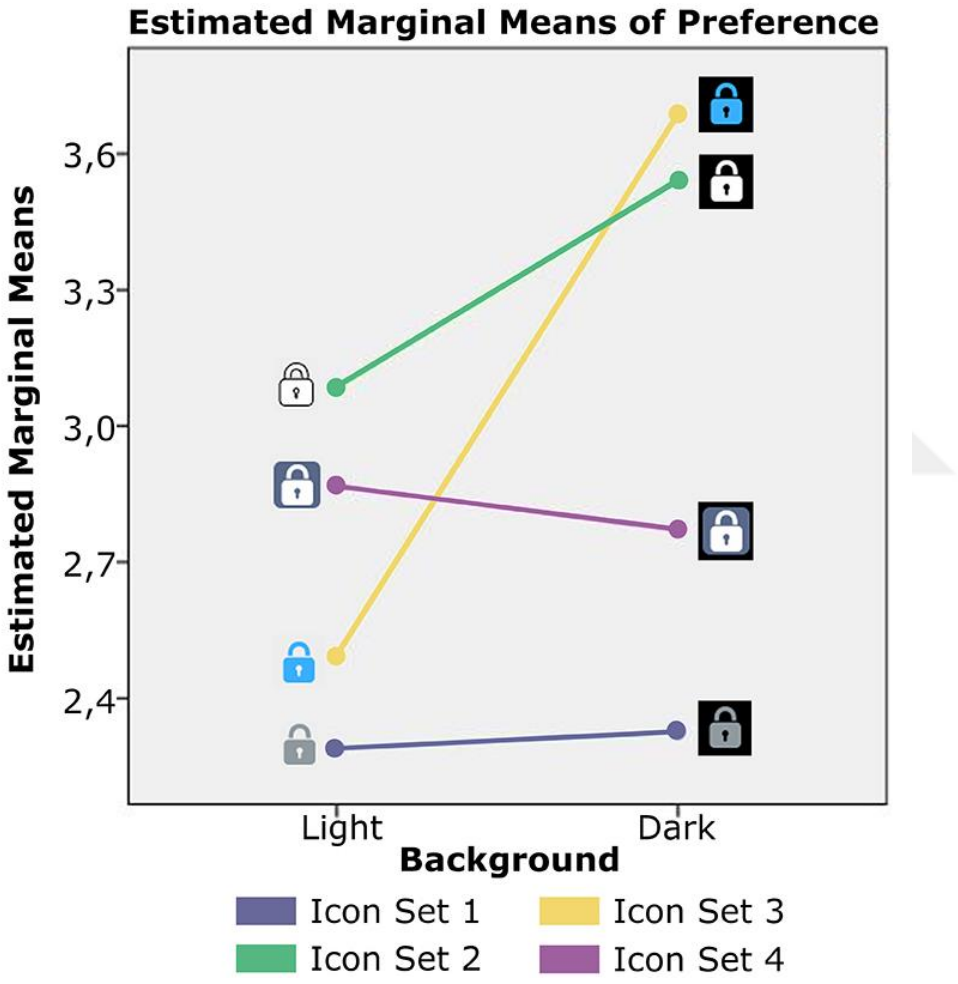


Figure 4.27 The participants' preferences on two backgrounds

In conclusion, results of the subjective evaluation ratings revealed that icon design and background color could affect participants' preferences significantly, so figure 4.27 shows that dark theme is more preferable than light theme except for icon set 4. Also, dark theme affected results dramatically for icon set 2 and icon set 3.A.

CHAPTER 5

CONCLUSION

5.1 Introductıon

This Chapter will introduce conclusion of this study and also, discuss the possible reasons of statistical results. In addition, some limitations in the study and points that should be considered in future studies will be mentioned.

5.2 Conclusion of the Study

This empirical study was conducted in order to understand effect of icon design and background color on users' performance and preferences. However while designing the alternative icon sets, in order to follow commonly used design trend to benefit from users' familiarity with that visualization styles, alternative icon sets were limited by only color change, so study was limited to explore the effects of figure/background contrast ratio of flat icon designs and background colors of theme. On the other hand, if the visual search test was conducted with completely different icon designs in terms of shapes, characteristic of different icon types such as familiarity, concreteness, semantics, etc. would be included in the test, so there would be several variables which could not be statistically compared as a result.

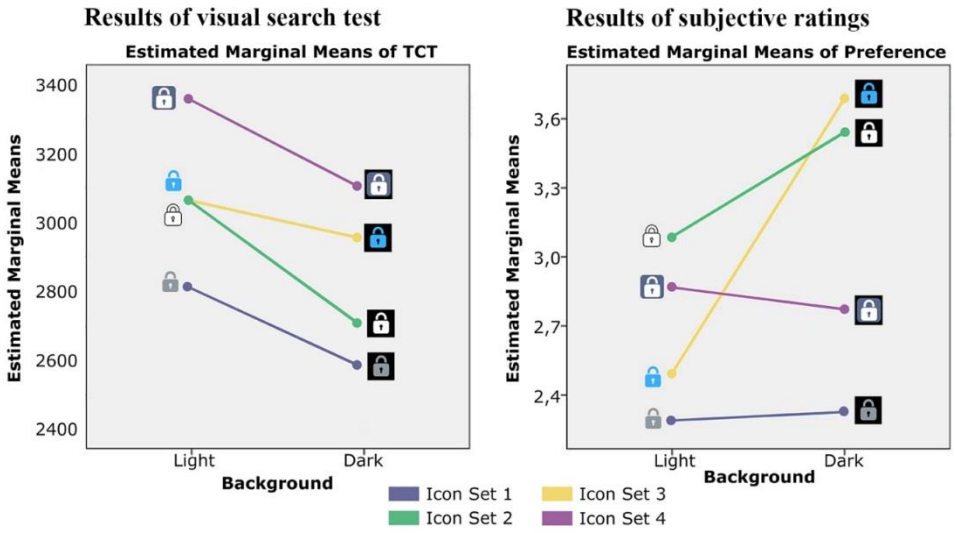


Figure 5.1 The results of participants' performance and preferences

The results of visual search test showed that on the dark background, there is a similarity between the rank of icons from the best to the worst in terms of participants' performance and rankings of contrast values from the highest to the lowest.

- Visual search performance on dark theme; 1 > 2 > 3 > 4 (there were no significant difference between icon set 1 and icon set 2 as a result of visual search test)
- Foreground/background contras ratio; 2 > 1 > 3 > 4

Therefore, it can be seen that the users' visual search performance increases in direct proportion with the contrast ratio of the icons with background. However, in the visual search test results of the icons on the light background, there is an inverse proportion according to the contrast ratio. In other words, the icon with the lowest contrast ratio is chosen best, while the icon with the highest contrast ratio seems to have the worst performance.

- Visual search performance on dark theme; 1 > 3 > 2 > 4 (there were no significant difference between icon set 2 and icon set 3 as a result of visual search test)
- Foreground/background contras ratio on light background; 1 > 3 > 2 > 4

According to WCAG (Web Content Accessibility Guidelinesw), contrast ratio of graphical objects should be at least 3:1 for better legibility. However, results on light background revealed that while icon set 4 has the worst performance with 5.5 contrast ratio, icon set 1 has the best performance with 2.87 contrast ratio. Performance results of icons on light theme showed that the rankings may change after a certain threshold is exceeded, rather than increased search performance with contrast directly. However, despite the lower contrast ratio than the standards of WCAG, icon set 1 got an unexpected result.

There would be 3 factors that caused this inconsistency about acceptable contrast ratio of graphical elements. First, WCAG may have determined the threshold of acceptable contrast ration high a bit by considering the users with visual impairments. Also, WCAG defines the intention of their criteria about contrast ratio as that text must be legible even for users with low vision by providing enough contrast. Second, the focal point of WCAG is the legibility of text on the screen, so icons with solid forms would have different results compared to text. The last one, contrast ratio is defined as brightness difference between foreground and background, so contrast values which were defined with software and the contrast that users see on the screen in real may differ depending on the brightness and color accuracy of the screen.

Another important result is that participants performed slightly better on dark theme than light theme although there is no significant difference between them as expected due to higher contrast. Also, the black circular background used as a dark theme may affect reaction time positively because such an eye-catching and high-contrast form which was positioned in the middle of the white page can make it easier and fast for participants to focus on this area, but further investigation is

needed. Also, the mean difference accepted significant at the ,05 level, but effects of background color could be accepted significant with ,054 level because the results showed that figure/background contrast ratio has crucial effects on users' performance, and background color is one of the most important elements of this contrast ratio, but the most important reason of not having a significant difference in background color in this study is that the chosen icon sets have similar contrast ratios on both backgrounds. Thus, the distinctiveness of the background color was limited.

Moreover, results of participants' preferences showed that background has significant effect on user preferences, so participants always preferred dark theme except for icon set 4. Also, the dramatic change in contrast ratios of set-2 and set-3 with the backgrounds seems to match the dramatic change in users' preference for dark theme. Besides that, the participants' preferences for the set-4 which is the option with the most balanced contrast ration with both backgrounds, also seems balanced. However, although there is a serious difference in the contrast ratios which are provided by the set-1 for both backgrounds, there is no significant difference in user preferences, but perhaps gray color may not be preferred by users since it creates a feeling of passivity due to its common use. Also these results revealed that there may be no significant correlation between users' performance and preferences, especially the results of icon set – 1 could be the indicator of that. In conclusion, icon set – 2 would be the best choice for the company in order to use it on their graphical user interfaces according to its balanced results from both users' performance and preferences in total.

5.3 Answers to the Main Research Questions

This study explored the effects of icon design and background color on users' visual search performance and preferences via conducting literature review and experimental study in order to reveal effects of each variable with statistical data. The idea of exploring design elements that may affect the performance and

preferences of users in military GUIs as the starting point of the study has turned into a study that its results would cover similar systems' GUIs in which user performance is important during the operation. As a result of the literature review and the test study conducted in this direction, the research questions determined at the beginning of the study also had the opportunity to find answers.

- *What are the effects of color use in icon design in GUI?*

  As one of the most important subjects of this study, both the literature review and the test revealed that the use of color in the GUI has important effects on users. The contrast provided by the use of colors on the foreground and background would make some visual elements more eye-catching in GUI. Therefore, users can be directed with use of color on warnings, buttons, icons, etc. in GUI in order to improve their reaction and visual search performance. Also, the statistical results of the participants' visual search performance revealed that background color has a significant effect on users' performance and preferences. In fact, results showed that figure/background contrast ratio affects users visual search performance, so the background color has an important effect on users' performance. It means that; the design of icon set where users can perform well on a light and dark theme is possible with color preferences that can provide sufficient and balanced contrast on both backgrounds. Therefore, therefore, color preferences can be an important factor for user performance and preferences in addition to providing visual hierarchy in GUI designs.

- *What is the effect of background color and figure/background contrast ratio on visual search performance?*

  Results of empirical study showed that increase in the figure/background contrast ratio leads to increase in visibility of the related visual elements, so usually they can be found faster on the screen. Besides affecting visual search performance, users' subjective preferences were affected by background color and contrast ratio according to results of study. Moreover,

the statistics analysis of participants' visual search performance also showed that the relation between contrasts and performance are mostly proportional for same icon set on both themes. Therefore while designing the interface, user performance will be positively affected if the color preferences of the icon or other visual elements are selected taking into account the contrast values with the background color.

- *Is it possible to design an icon set that would provide similar visual search performance on both light and dark themes?*

  According to the results, when the performance of the same icon sets on a dark and light theme were examined, it was observed that the icon sets with balanced contrast ratio with both background colors gave more consistent results in terms of user performance and preferences. Therefore, it would be possible to design such an icon with reasonable color choices for both background and foreground in GUI.

- *What is the effect of icon design and background color on users' preferences?*

  According to the statistical results of ANOVA, background theme has a significant effect on users' preferences. Higher contrast values of tested icon sets on dark background may lead to users to like the icons on dark theme more. Therefore, it can be paid attention to provide high contrasts while determining the colors of visual elements and theme in GUI design.

- *Is there any correlation between users' visual search performances and their preferences?*

  According to the statistical results, there is no significant correlation between users' performance and preferences because in the user preferences, the personal tastes of the users are more dominant than their

performance probably, so it may be more accurate to focus on what the users do rather than what they say in such performance tests. Thus, users should be involved in the design processes by taking into account the results of their performance tests rather than their opinions.

In summary, this study provides beneficial results in terms of effects of icon design and background color on users' performance and preferences for most GUI designs from different sectors which pay attention to user performance. Although some inconsistencies about users' performance and preferences could be tolerated thanks to high number of participants, more accurate results about effect of different variables for visual search performance could be obtained if test were performed more than once by defining different target icons. In addition, icon designs for this study were limited only by color changes, but in future studies, similar performance tests can be performed by keeping the colors constant and changing design styles by benefit from results of this study. Also, using the black circular background for test of dark theme may affect the reaction time of participants positively, so changing the color of the entire screen for different theme tests in future studies may give more consistent results.

REFERENCES

Andreessen, M. (2011, August 20). Why Software Is Eating The World. Retrieved June 12, 2020, from https:\\www.wsj.com/articles/SB10001424053111903480904576512250915629560

Bevans, R. (2020, August 04). A Quick Guide to Experimental Design: 4 Steps & Examples. Retrieved October 16, 2020, from https://www.scribbr.com/methodology/experimental-design/

Bhattacharyya, D., Chowdhury, B., Chatterjee, T., Pal, M., & Majumdar, D. (2014). Selection of character/background colour combinations for onscreen searching tasks: An eye movement, subjective and performance approach. Displays, 35(3), 101-109. doi:10.1016/j.displa.2014.03.002

Böcker, M. (1993, May). A multiple index approach for the evaluation of pictograms. Proceedings of the Fourteenth International Symposium of Human Factors in Telecommunication (pp. 73–84).

Brockmann, R.J. (1991). The unbearable distraction of color. IEEE Transactions on Professional Communication, 34, 153-159.

Designwonderful (n.d.). Design Wonderful: UI/UX Edition. Retrieved from https://designwonderful.wordpress.com/page/2/

Ehn, P., & Löwgren, J. (1997). Design for Quality-in-use: Human-Computer Interaction Meets Information Systems Development. *Handbook of human computer interaction* (pp. 299-313). North-Holland.

Gatsou, C., Politis, A., & Zevgolis, D. (2011). From icons perception to mobile interaction. 2011 Federated Conference on Computer Science and Information Systems (FedCSIS), 705-710.

Gittins, D. (1986). Icon-based human–computer interaction. International Journal of Man-Machine Studies, 24(6), 519–543. https://doi.org/10.1016/S0020-7373(86)80007-4

Gupta, S (n.d.) .Literature Review of Icon Design. Retrieved from http://www.sunakshigupta.com/icon

Harley, A. (2016, August 7). Visual Indicators to Differentiate Items in a List. Retrieved from https://www.nngroup.com/articles/visual-indicators-differentiators/

Historyoficons (n.d) . History of Icons. Retrieved from http://www.historyoficons.com

Huang, Kuo-Chen. (2008). Effects of computer icons and figure/background area ratios and color combinations on visual search performance on an LCD monitor. Displays. 29. 237-242.

Icon8 (n.d) . Icons. Retrieved from http://icon8.com/icons

Jansen, B. J. (1998). The Graphical User Interface: An Introduction. SIGCHI Bulletin. 30(2), 22-26.

Johnson, S. (2013, September 1). The Rise of Flat Design: Will going flat with site designs for Web and mobile work? Retrieved from https://www.targetmarketingmag.com/article/the-rise-flat-design-will-going-flat-site-designs-web-mobile-work/all/

Krug, S. (2006). Dont make me think: a common sense approach to web usability (2nd ed.). Berkeley, CA: New Riders.

Krug, S. (2014). Don’t make me think, revisited : A common sense approach to web usability. Berkeley, CA: New Riders.

Lindberg, T., & Näsänen, R. (2003). The effect of icon spacing and size on the speed of icon processing in the human visual system. Displays, 24(3), 111–120. https://doi.org/10.1016/S0141-9382(03)00035-0

Luo, S., & Zhou, Y. (2014). Effects of smartphone icon background shapes and figure/background area ratios on visual search performance and user preferences. Frontiers of Computer Science, 9, 751-764.

Marcus, A. (1997). Graphical User Interfaces. M.G. Helander, T.K. Landauer, P.V. Prabhu (Eds). *Handbook of Human-Computer Interaction* (2nd ed.). Elviser Science B.V.

McDougall, S. J., Curry, M. B., & de Bruijn, O. (1999). Measuring symbol and icon characteristics: norms for concreteness, complexity, meaningfulness, familiarity, and semantic distance for 239 symbols. *Behavior research methods, instruments, & computers : a journal of the Psychonomic Society, Inc*, *31*(3), 487–519. https://doi.org/10.3758/bf03200730

Meyer, K. (2017, September 3). Flat UI Elements Attract Less Attention and Cause Uncertainty. Retrieved from https://www.nngroup.com/articles/flat-ui-less-attention-cause-uncertainty/

Nielsen, J. (2001, August 4). First Rule of Usability? Don't Listen to Users. Retrieved May 14, 2020, from https://www.nngroup.com/articles/first-rule-of-usability-dont-listen-to-users/

Nielsen, J. (2005, August 14). Putting A/B Testing in Its Place. Retrieved June 11, 2020, from https://www.nngroup.com/articles/putting-ab-testing-in-its-place/

Perkins, R., Keller, D.S., & Ludolph, F. (1997). Inventing the Lisa user interface. Interactions, 4, 40-53.

Post, D.L. (1997). Color and Human-Computer Interaction. In Helander, M., Landauer, T. K., & Prabhu, P. V., Handbook of human-computer interaction (574-611). Amsterdam: Elsevier.

Robert C. Murphy (2006, October 1). The Effect of Target Color and Contrast on Movement Times in Aimed Movement Tasks.

Rohrer, C. (2014, October 12). When to Use Which User-Experience Research Methods. Retrieved June 1, 2020, from https://www.nngroup.com/articles/which-ux-research-methods/

Schröder, S., & Ziefle, M. (2008). Effects of Icon Concreteness and Complexity on Semantic Transparency: Younger vs. Older Users. ICCHP.

Shattuck, Nita & Matsangas, Panagiotis & Shattuck, Lawrence. (2008). Fatigue and its effect on performance in military environments.

Shen, Z., Zhang, L., Xiao, X., Li, R., & Liang, R. (2020). Icon Familiarity Affects the Performance of Complex Cognitive Tasks. i-Perception, 11(2), 2041669520910167. https://doi.org/10.1177/2041669520910167

Smith D.C., Irby C., Kimball R., Harslem E. (2001) The Star User Interface: An Overview. In: Hansen P.B. (eds) Classic Operating Systems. Springer, New York, NY.

Smith (2016). The New Logo from Instagram Marks the Beginning of the End of "Flat Design". Retrieved from https://smithhousedesign.com/new-logo-instagram-marks-beginning-end-flat-design/

Spiliotopoulos, K., Rigou, M., & Sirmakessis, S. (2018). A Comparative Study of Skeuomorphic and Flat Design from a UX Perspective.

Tullis, T.S. (1997). Screen Design. In Helander, M., Landauer, T. K., & Prabhu, P. V., Handbook of human-computer interaction (503-528). Amsterdam: Elsevier.

WebAIM (n.d) . Contrast Checker. Retrieved from http://www.webaim.org/resources/contrastchecker

Wickens, C. D. (1992). Engineering psychology and human performance (2nd ed.). New York: HarperCollins Publishers

99designs (2016). Skeuomorphism vs flat design vs material design. Retrieved from 99designs.com/blog/trends/skeuomorphism-flat-material-design

APPENDICES

A. Consent Form

ARAŞTIRMAYA GÖNÜLLÜ KATILIM FORMU

Bu araştırma, ODTÜ Endüstri Ürünleri Tasarımı Bölümü Yüksek Lisans öğrencisi Barış Bumin tarafından yüksek lisans tezi kapsamında yürütülmektedir. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Çalışmanın Amacı Nedir?

Çalışmanın amacı grafiksel kullanıcı arayüzlerinde farklı ikon tasarımlarının ve arka plan renklerinin kullanıcıların arama performanslarına ve kullanıcıların kişisel beğenilerine etkilerini araştırmak ve bunlar arasındaki ilişkiyi incelemektir.

Bize Nasıl Yardımcı Olmanızı İsteyeceğiz?

Çalışma kapsamında kullanıcıların arama performanslarını ölçmek adına bilgisayar ekranında görüntülenecek ve fare ile kullanılan bir yazılım tasarlanmıştır.Veri toplamak için tasarlanan yazılım 4 farklı ikon setinin, 2 farklı arkaplan renginde toplamda 8 kere gösteriminden oluşmaktadır ve her gösterimde kullanıcının önceden belirlenen ikonu o gösterimdeki ikon seti içerisindeki 16 farklı ikon arasından seçmesinin istenecektir. Bu sırada her gösterim için kullanıcının görevi kaç saniye içerisinde tamamlayabildiğinin kaydı bu yazılım tarafından tutulacaktır. Kayıtlarda katılımcının adı kullanılmayacak, kullanıcılar sıra numaraları ile kodlanacaktır. Performans testi sonucunda ise kullanıcının her bir ikon setinin 2 farklı arkaplan rengi üzerindeki görüntülerini kişisel beğenilerine göre likert ölçeğiyle notlamaları istenecektir. Herbir kullanıcı için excelde tutulan sayısal veriler, test sonunda ANOVA yöntemi ile analiz edilerek değişkenlere bağlı anlamlı farklılıklar incelenecektir.

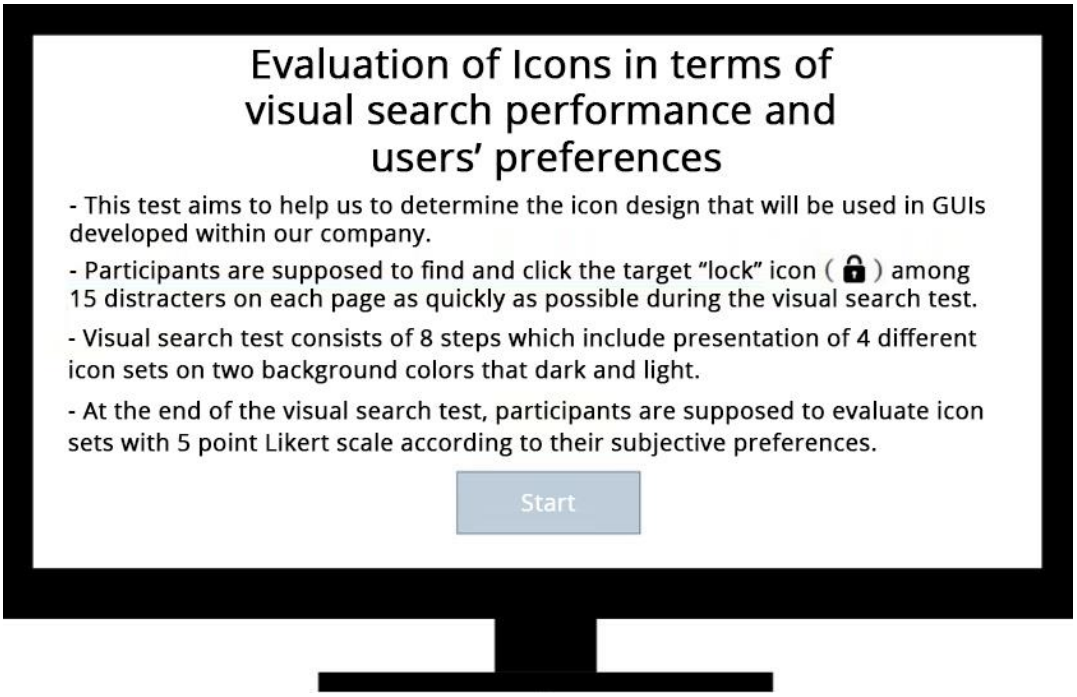
Araştırmayla ilgili daha fazla bilgi almak isterseniz:

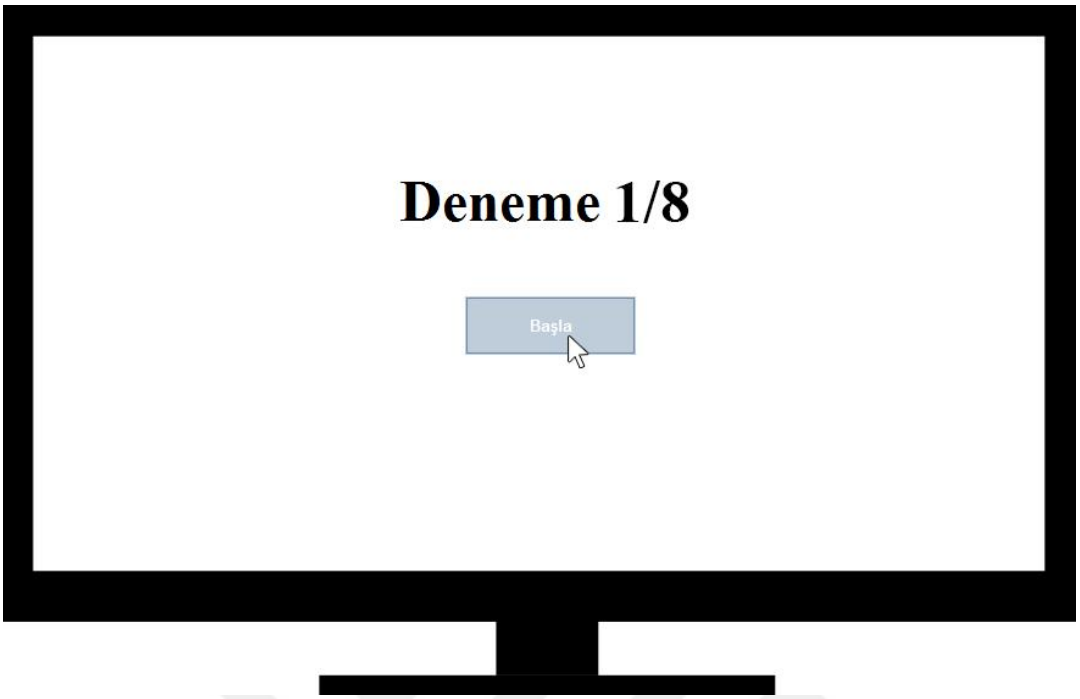
Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Araştırma hakkında daha fazla bilgi almak için araştırmayı yürüten ODTÜ Endüstri Ürünleri Tasarımı Bölümü yüksek lisans öğrencisi Barış Bumin (E-posta: bumin.baris.bb@gmail.com) ile iletişim kurabilirsiniz.

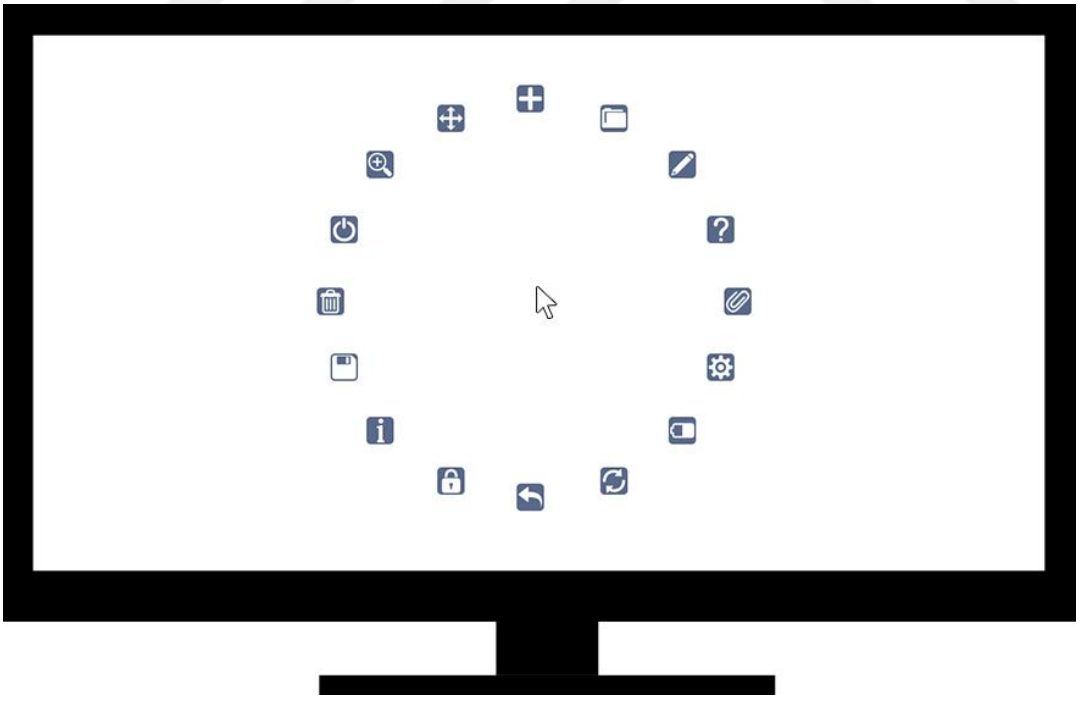
Yukarıdaki bilgileri okudum ve bu çalışmaya tamamen gönüllü olarak katılıyorum.

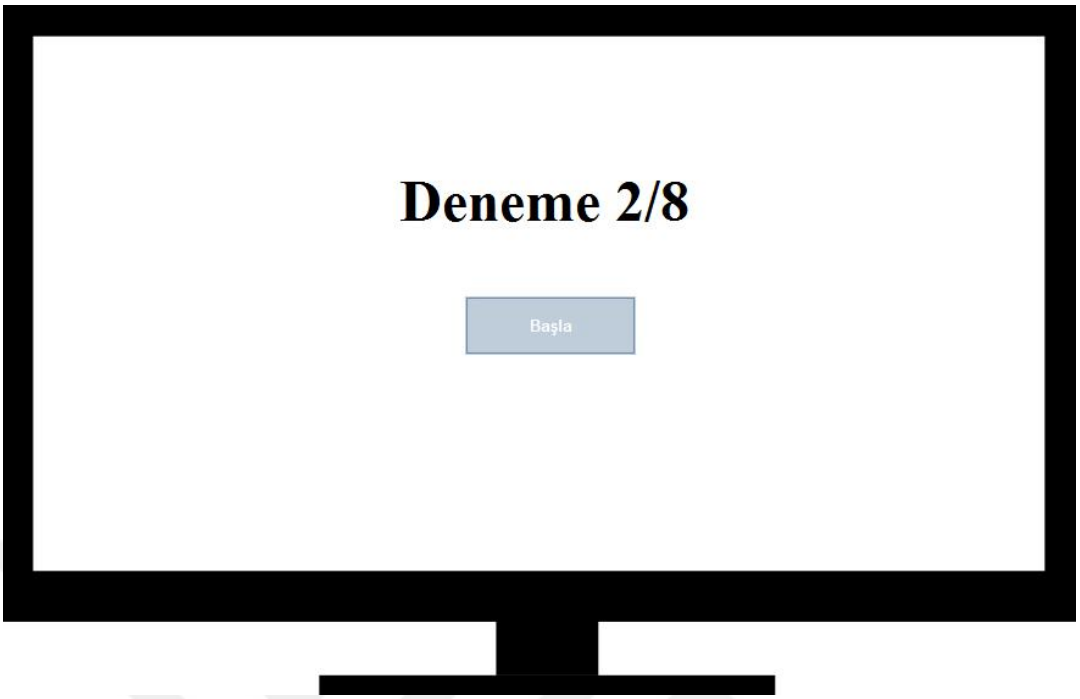
Katılımcının İsim Soyad	Tarih	İmza
Görüşmecinin İsim Soyad	Tarih	İmza

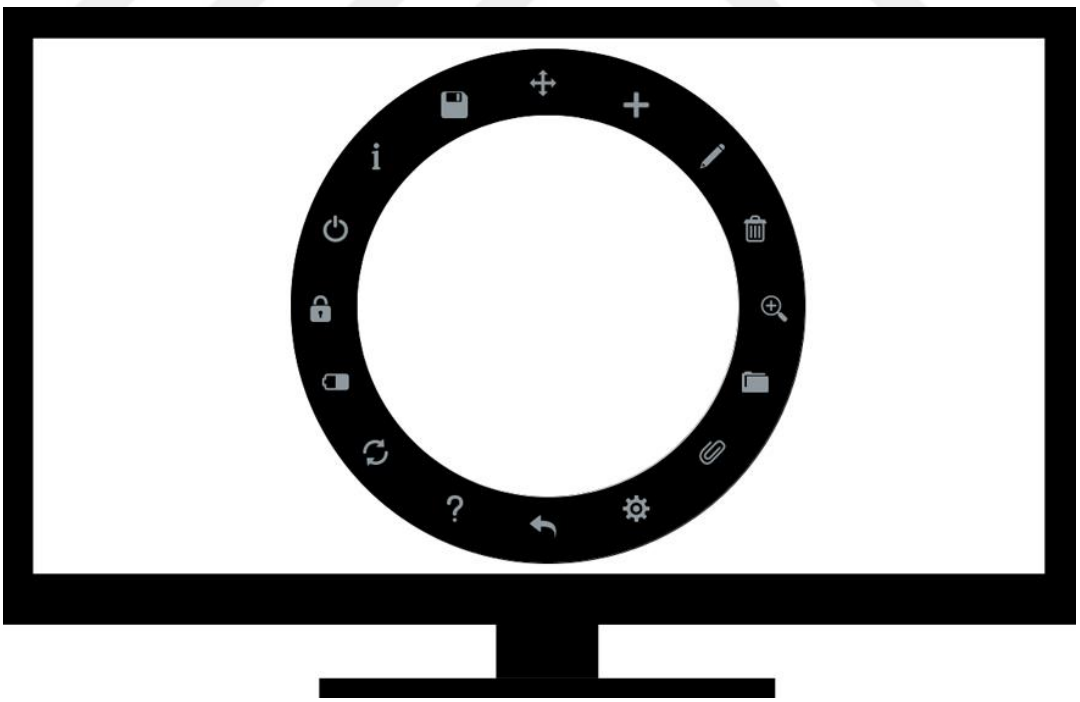
B. The order of the test-screens shown **to the participants during the** experiment.

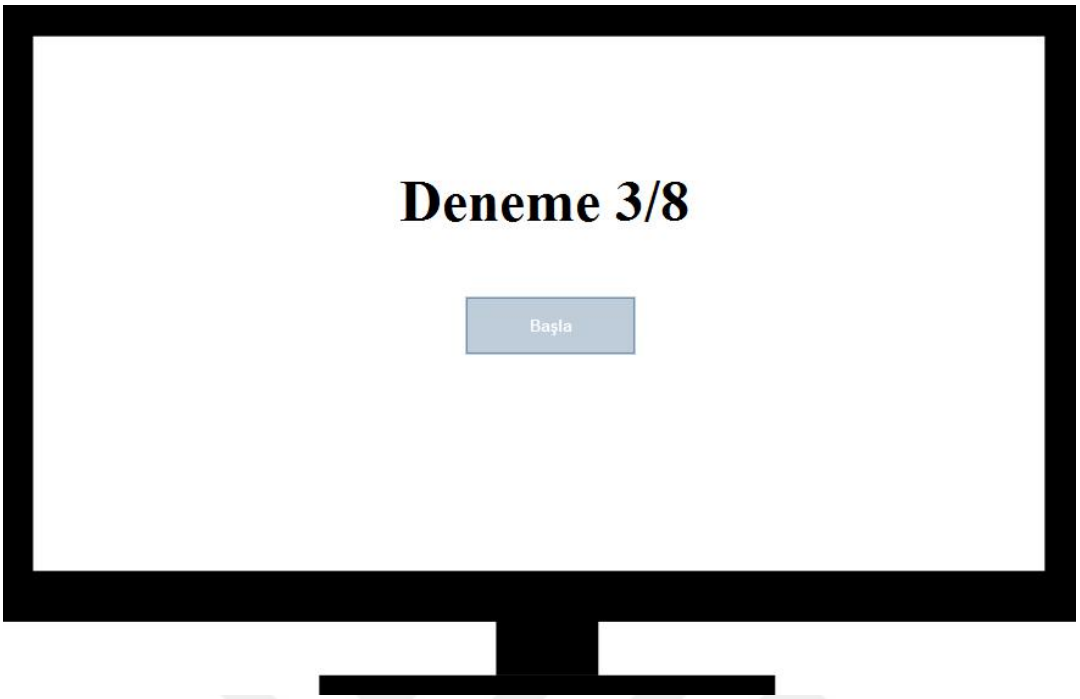


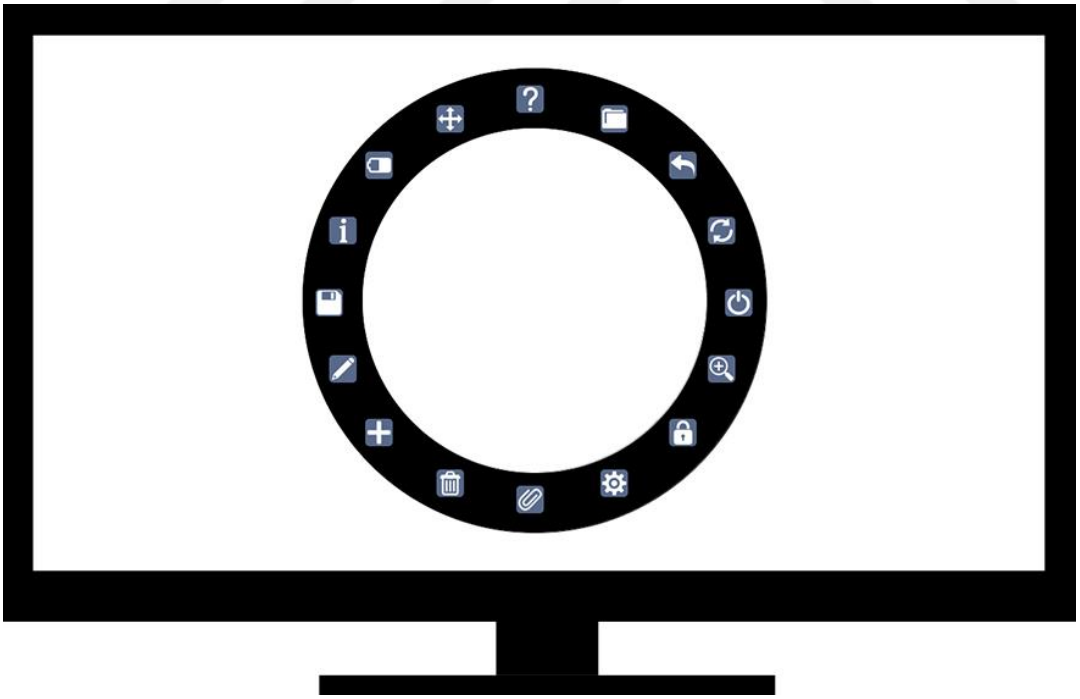

Deneme 1/8
Başla

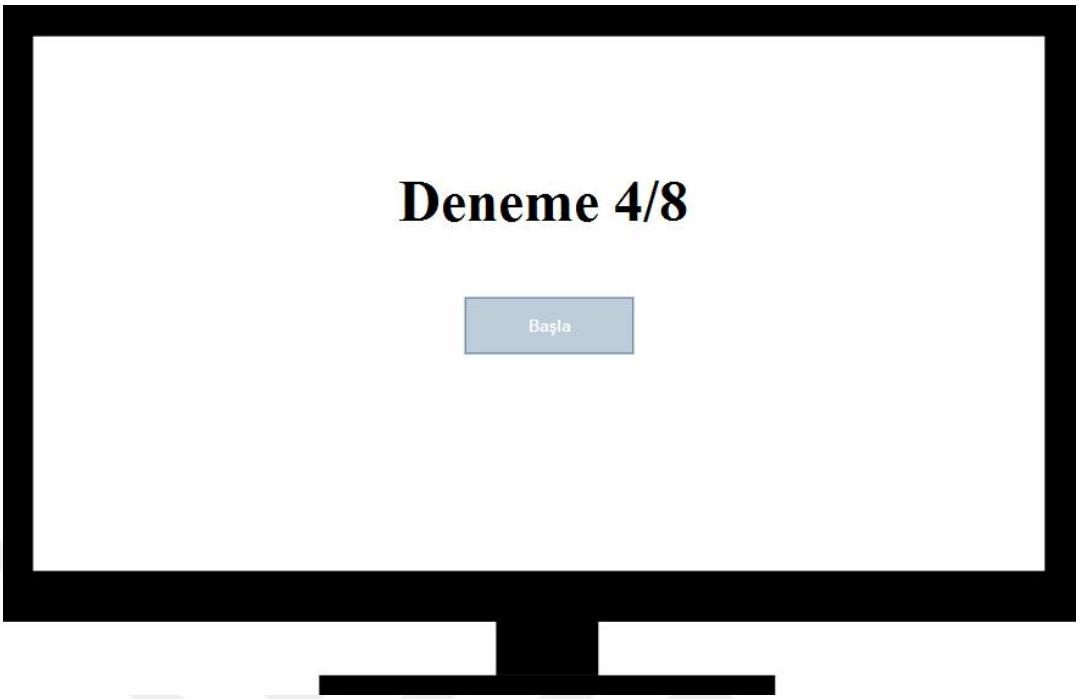


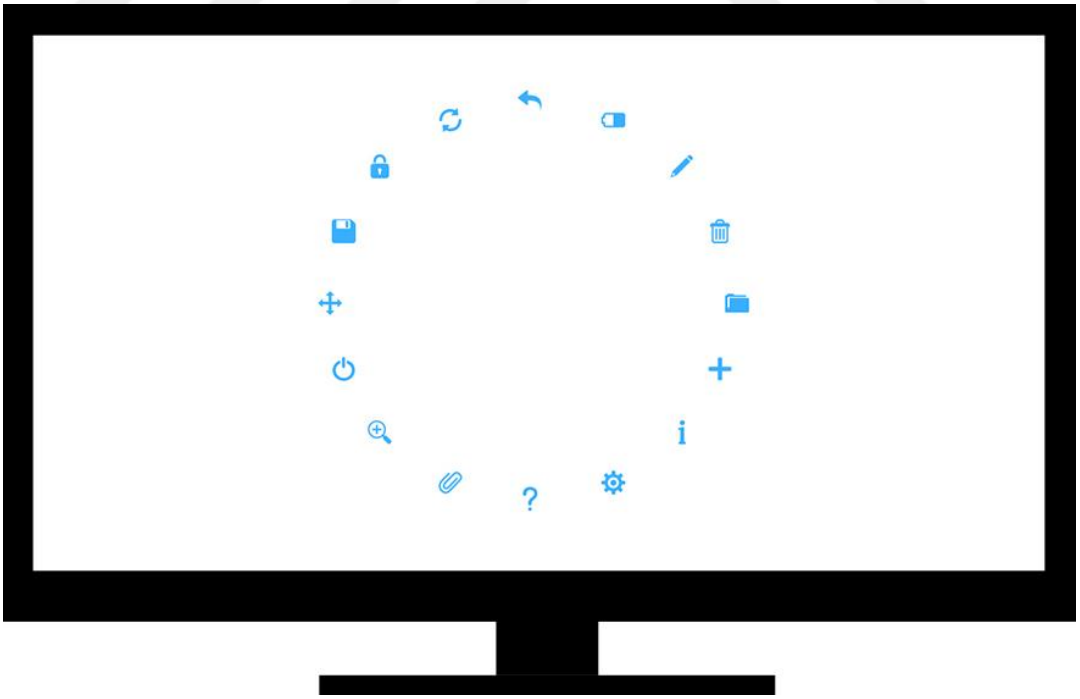

Deneme 2/8
Başla

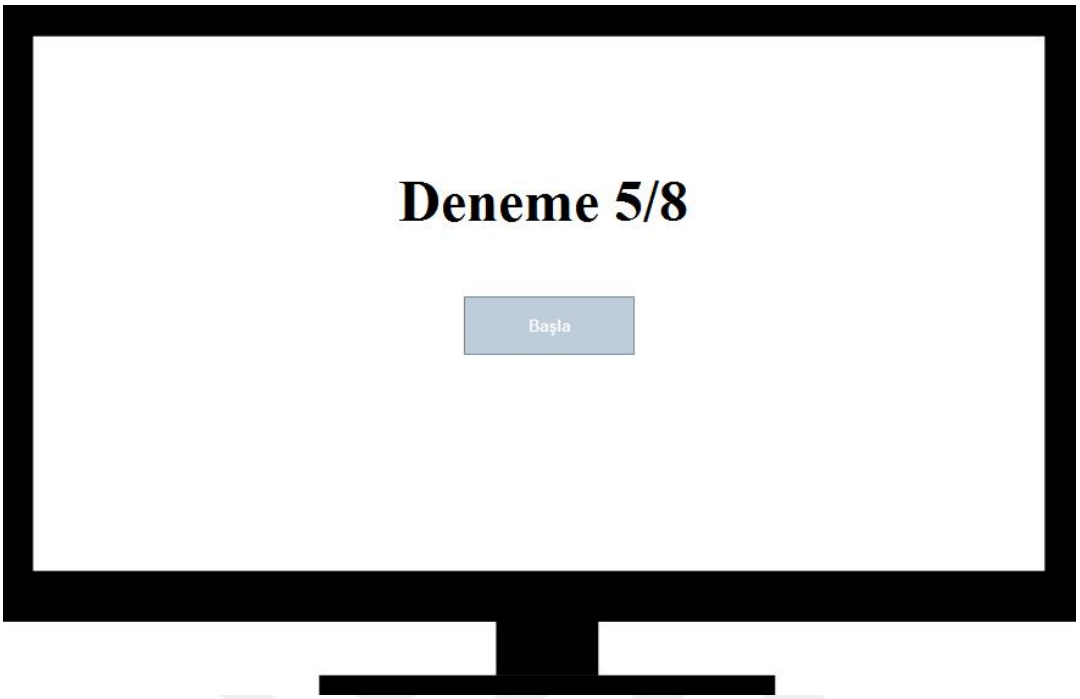


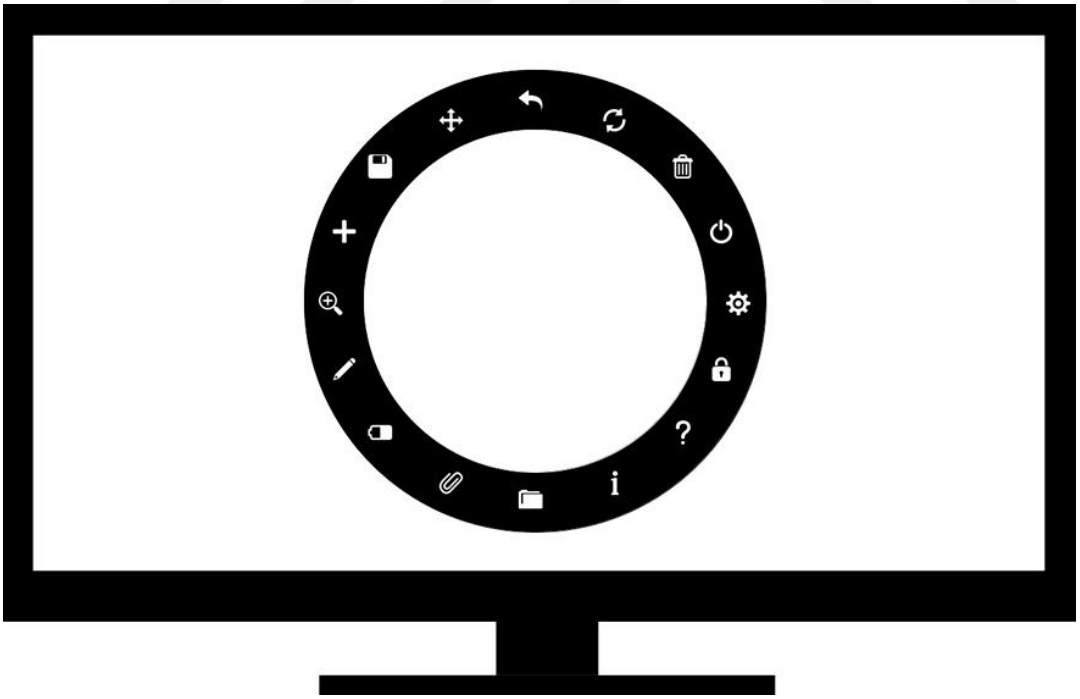

Deneme 3/8
Başla

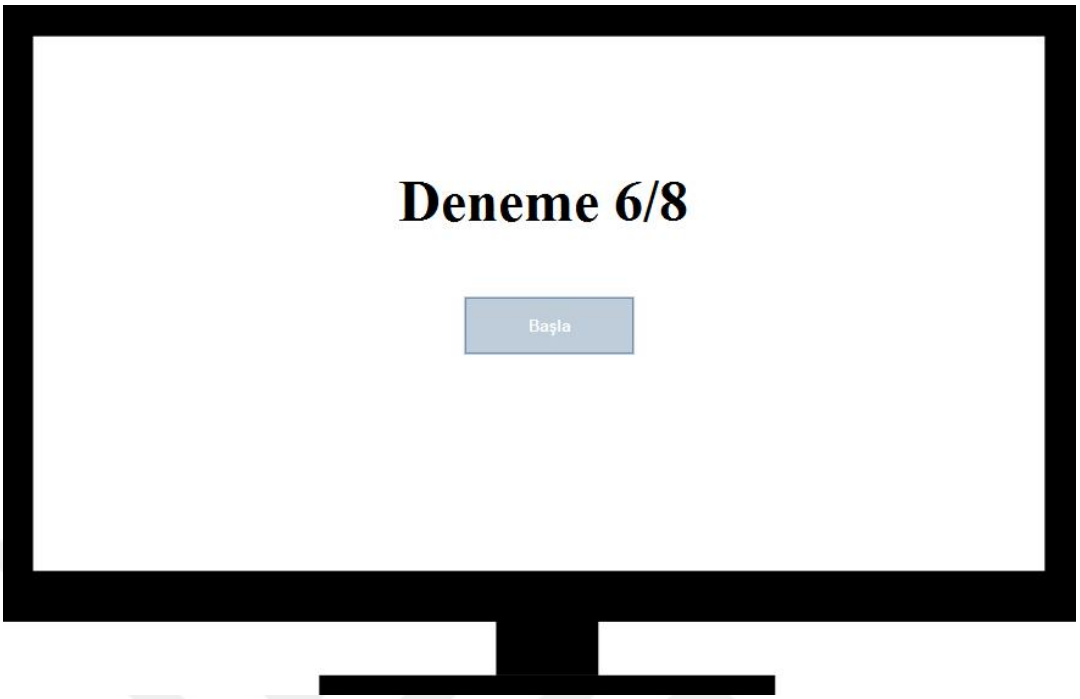


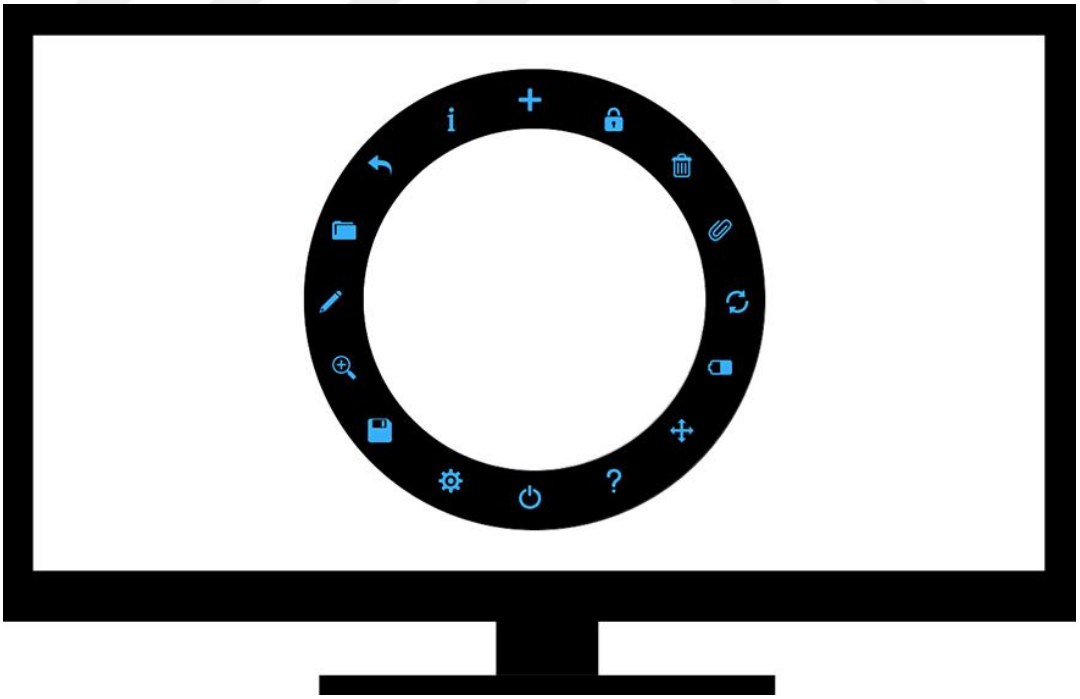

Deneme 4/8
Başla

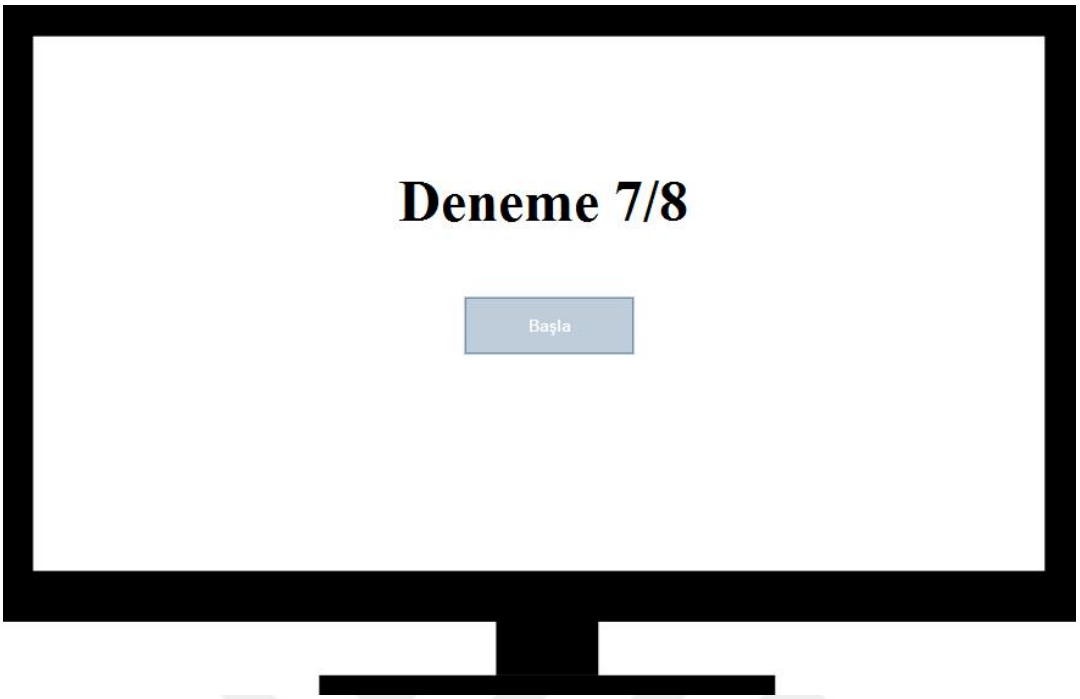


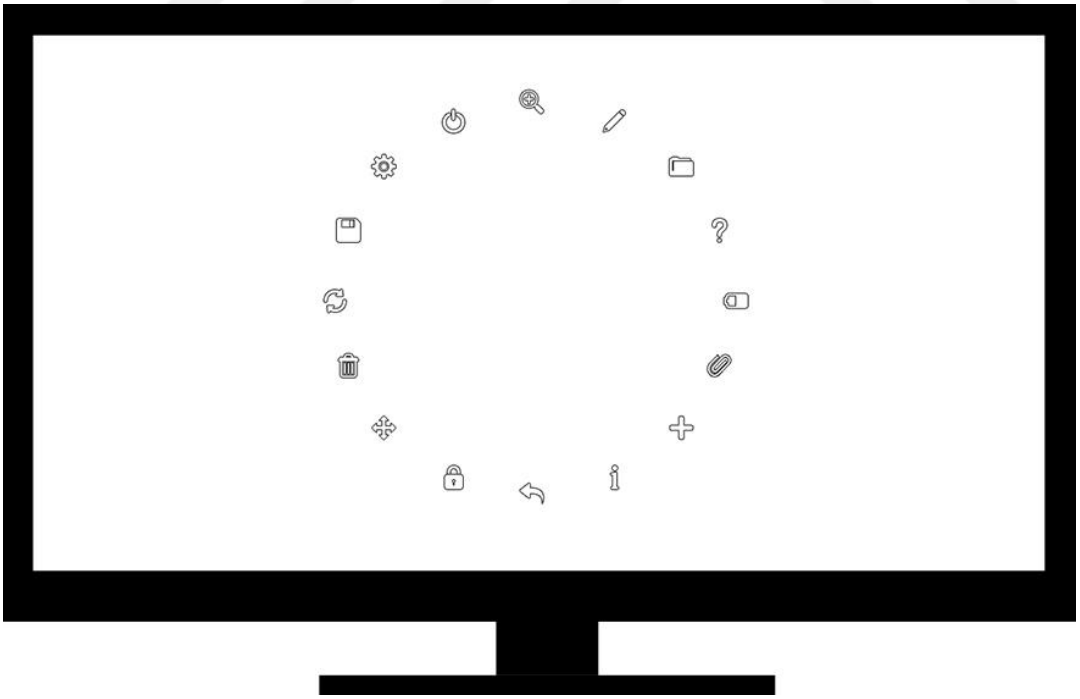

Deneme 5/8
Başla

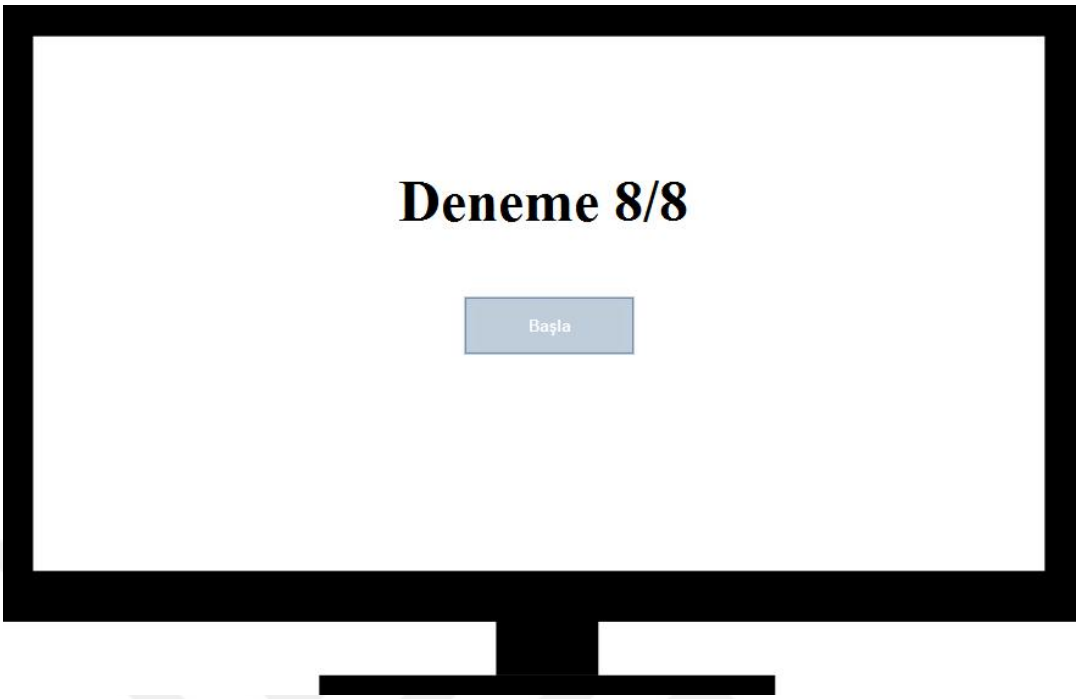


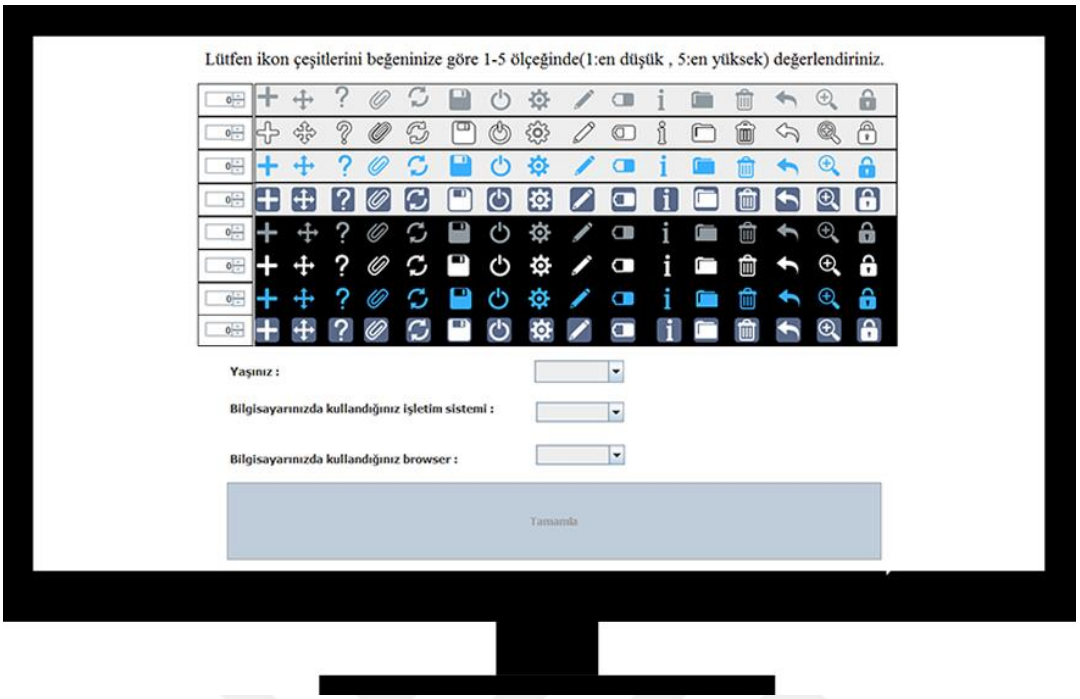

Deneme 6/8
Başla

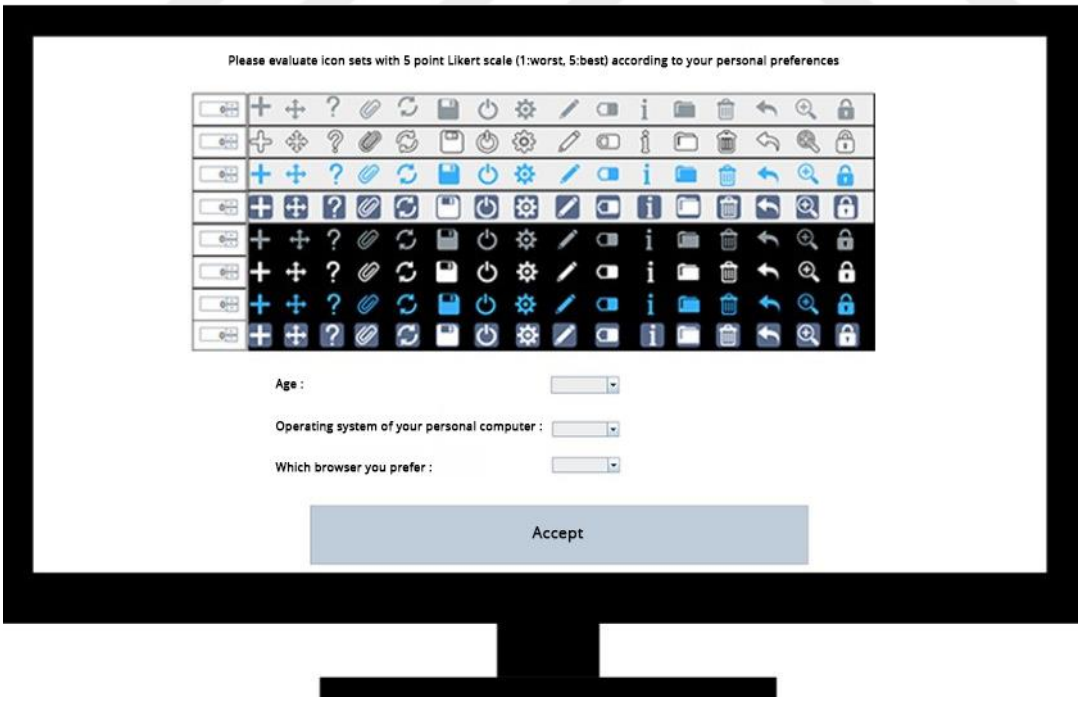



Deneme 7/8
Başla




Deneme 8/8
Başla


Lütfen ikon çeşitlerini beğeninize göre 1-5 ölçeğinde(1:en düşük , 5:en yüksek) değerlendiriniz.
Yaşınız :
Bilgisayarınızda kullandığınız işletim sistemi :
Bilgisayarınızda kullandığınız browser :
Tamamla


Please evaluate icon sets with 5 point Likert scale (1:worst, 5:best) according to your personal preferences
Age :
Operating system of your personal computer :
Which browser you prefer :
Accept