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ASSESSING USABILITY OF VIRTUAL REALITY
FOR BASIC DESIGN EDUCATION

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ASSESSING USABILITY OF VIRTUAL REALITY FOR BASIC DESIGN EDUCATION

A Master's Thesis

by

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Interior Architecture and Environmental Design
İhsan Doğramacı Bilkent Üniversitesi
Ankara

July 2018

To my family…

ASSESSING USABILITY OF VIRTUAL REALITY FOR BASIC DESIGN EDUCATION

The Graduate School of Economics and Social Sciences
of
İhsan Doğramacı Bilkent University

by

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INTERIOR ARCHITECTURE AND ENVIRONMENTAL DESIGN
İHSAN DOĞRAMACI BİLKENT UNIVERSITY
ANKARA

July 2018

I certify that I have read this thesis and have found that is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts in Interior Architecture and Environmental Design.

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ABSTRACT

ASSESSING USABILITY OF VIRTUAL REALITY FOR BASIC DESIGN EDUCATION

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Being an emerging technology, virtual reality is used in a wide range of fields such as medicine, gaming, psychology and sociology. There are also wide range of researches that compare traditional and digital methodologies in design education. However, in design education, there is a limited research into the implementation of virtual reality (VR). Therefore, this thesis focuses on the usability of virtual reality in design education, especially during problem-solving activity in basic design education.

This thesis presents the basic design education literature in terms of digital approaches, virtual reality technologies, usability criteria and also technology acceptance model. In order to to analyze the usability of virtual reality in basic design education, an experimental study conducted with 20 first year interior architecture and architecture students in the Spring semester of 2017-2018 academic year, at Bilkent University. It is found that there is a statistically significant difference in terms of intention to use and perceived enjoyment between the VR group and paper-based group. Moreover, there is also a statistically significant effectiveness difference between of VR and paper-based environment. As a result of that, it is stated that VR can support problem-solving activity of basic design education.

Keywords: Basic Design Education, Technology Acceptance Model, Usability, Virtual Reality

ÖZET

TEMEL TASARIM EĞİTİMİ İÇİN SANAL GERÇEKLİĞİN KULLANILABİLİRLİĞİNİN DEĞERLENDİRİLMESİ

Özgen, Dilay Seda

İç Mimarlık ve Çevre Tasarımı Yüksek Lisans Programı

Tez Danışmanı: Doç. Dr. Yasemin Afacan
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Temmuz 2018

Gelişen bir teknoloji olan sanal gerçeklik, tıp, oyun, psikoloji ve sosyoloji gibi alanlarda kullanılmaktadır. Tasarım eğitiminde de geleneksel ve dijital metodolojileri karşılaştıran çok çeşitli araştırmalar vardır. Bununla birlikte, tasarım eğitiminde, sanal gerçekliğin kullanıldığı sınırlı araştırma bulunmaktadır. Bu nedenle, bu çalışmada sanal gerçekliğin, temel tasarım eğitiminde ve özellikle problem çözme aktivitesinde kullanılabilirliği üzerinde durulmuştur.

Bu çalışma, temel tasarım eğitimi literatürünü, dijital yaklaşımlar, sanal gerçeklik teknolojileri, kullanılabilirlik kriterleri ve teknoloji kabul modelini sunmaktadır. Kullanılabilirliği değerlendirmek için, VR (sanal gerçeklik) grubu ve kağıt tabanlı grup olan iki farklı grup oluşturuldu. Bu deney 20 kişilik birinci sınıf iç mimarlık ve mimarlık bölümleri öğrencileriyle 2017-2018 Bahar akademik yarıyılı içerisinde Bilkent Üniversitesinde yapıldı. Araştırma sonuçlarına göre kullanmaya yönelim ve algılanmış beğeni açısından iki grup açısından (VR ve kağıt tabanlı grup) istatiksel bir fark bulunmuştur.

Buna ek olarak oluşturulan iki grup arasında etkililik açısından istatiksel bir fark bulunmuştur. Bu sebeple VR , temel tasarım eğitiminin problem çözme aktivitesini destekleyebilmektedir.

Anahtar Sözcükler: Etkililik, Kullanılabilirlik, Sanal Gerçeklik, Teknoloji Kabul Etme Modeli, Temel Tasarım Eğitimi

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LIST OF ABBREVIATION

AR	Augmented reality
ISO	International Organization for Standardization
IU	Intention to use
PE	Perceived enjoyment
PEU	Perceived ease of use
PIU	Paper-based intention to use
PPE	Paper-based perceived enjoyment
PPEU	Paper-based perceived ease of use
PPU	Paper-based perceived usefulness
PT	Presence Test
PU	Perceived Usefulness
TAM	Technology Acceptance Model
TFT	Technology Familiarity Test
VIU	Virtual reality intention to use
VPE	Virtual reality perceived enjoyment
VPEU	Virtual reality perceived ease of use
VPU	Virtual reality perceived usefulness
VR	Virtual reality
VRE	Virtual reality environment

CHAPTER I

INTRODUCTION

In the era of technology, using computers and other technologies in design is inevitable. Until the 90s, design education had been taught by traditional ways. However, today computer aided design has a great value on design education. As a result of that, design process is improved in shorter times flexibly and alternatively (Liu, 2006). Today, digital methodologies enhance the precise capabilities of productive and performative processes that never existed in previous traditional, paper-based methods. They also change the traditional processes and layout of traditional design (Oxman, 2008). Oxman (2008) put forward the idea that students must know conceptual foundations and strategies of new digital technologies, therefore they can present new approaches to project their ideas fluently because digital techniques provide students distinct thinking mechanisms. “Digital methodologies today are enhancing certain capabilities of generative and performative processes that were never available in conventional, paper-based methods. As a result, traditional concepts of (paper-based) representation today lose their centrality as a conceptual basis for explicating the processes and knowledge associated with digital design” (Oxman, 2008:102). In addition, VR technologies have a place on design education. Portman, Natapov and Fisher-Gewirtzman (2015) mentioned the strong potential of VR in design. Rieuf, Bouchard, Meyrueis and Omhover (2017) stated that VR is simple, manageable, motivating, agreeable and pleasant for sketching in early stage design.

Usability is a term, where a prototype or any product is evaluated by individuals or teams (Nielsen & Molich, 1990; Nielsen, 1993). This evaluation leads to improve and test the existing systems and/or prototypes. In order to test virtual reality (VR) Usability evaluations are widely used in this system. Because of VR is the technology that has been developing day by day, it is the popular tool for scientific literature to investigate in different areas as medicine, psychology, education, etc. VR is also deeply investigated in education literature to understand how usable it is.

1.1 Problem Definition and Thesis Objectives

Briefly, VR has the potential to support problem-solving activity in basic design education. Additionally, there are different types of usability measures for VR as TAM and ISO standards. However, there is limited information and studies (Heydarian, Pantazis, Gerber & Becerik-Gerber, 2015b; Rieuf, et al., 2017) in terms of the usability of VR in design field. Thus, this thesis aims to find whether there is any statistical difference between usability of VR and paper-based environment in the process of basic design problem-solving activity.

As part of the education literature, this thesis analyzed the usability of VR in the basic design education. In order to understand that it is asked that can virtual reality adequately support problem solving activity of basic design education? The aim of this experimental study is understanding the usability of VR in basic design in terms of effectiveness and technology acceptance model (TAM). Although efficiency is explained and defined under International Organization for Standardization (ISO), in this thesis will be disregard because of lack of equipment.

1.2. Structure of Thesis

This thesis contains five chapters. In Chapter 1, a brief introduction is followed by the definition of problem. In Chapter 2, first, definition of basic design and basic design education were given. Then, elements of basic design, and its principles are explained deeply. In addition to that, explanation of digital approaches for basic design problem solving activity are followed. In Chapter 3, virtual reality is defined and explained in terms of immersion, architectural design and design problem-solving activity. Then, usability is followed in a content of virtual environment systems. Then, ISO standards are discussed as efficiency, effectiveness and satisfaction criteria. Technology acceptance model also is a part of usability concept. It is conceived under the satisfaction criteria of usability because it is a heuristic evaluation model. TAM has four different components which are perceived usefulness, perceived ease of use, intention to use and perceived enjoyment explained in this part. In Chapter 4, first, research questions and hypotheses are presented, then the setting of the study, participants and instruments are explained, respectively. In Chapter 5, the results are divided into the two categories, which are descriptive analysis of usability of virtual reality and comparison of virtual reality and paper-based environment. In the comparison analysis, effectiveness test, TAM findings are analyzed. This analysis contains descriptive results, correlation and regression results, and finally independent and paired samples t test results. Finally, overall discussion of the findings is presented. Chapter 6 is the conclusion of the thesis.

CHAPTER II

BASIC DESIGN EDUCATION

2.1. What is Basic Design and Basic Design Education?

In design disciplines, such as architecture, industrial design, interior design, graphic design and landscape architecture, basic design education deals with a grammar of visual language. Wong (1993) states that this language is the root of design creation, which design students must deal with and be accoutered with the knowledge of principles, rules and concepts of visual organization so that they can broaden their capability in visual organization. Recognition of visual sophistication is the elementary aim of basic design education (Zelanski & Fisher, 1996). Moreover, basic design education also aims to raise awareness and provide visual sensitivity in transferring an image onto the design field (Akbulut, 2010).

“Design is a heterogeneous process” Jormakka (2014) and he stated that design is approaches, strategies and methodologies which are affected by experience of designers. Within his idea basic design is also a methodology and approach. Basic

Design is defined as the pedagogy, through which holistic, creative and experimental abilities are encouraged and diverse learning styles and cognitive thinking are developed based on the fundamental principles of design (Boucharenc, 2006). Basic design education is the expression of these abilities in aesthetic level and transfer of thinking, emotions, and impressions of a person (Beşgen, Kuloglu & Fathalizadehalemdari, 2015).

2.2 The History of Basic Design Education

In 1918, Bauhaus School was established that considering creativity can be learnable and teachable thanks to foundation courses. Therefore, it was laid a foundation of today's understanding of basic design course. In 1919, Walter Gropius founded the first design school in Germany called 'Bauhaus' (Itten, 1975). Bauhaus institution has initiated the design education to collaborate industry and design. Understanding of Bauhaus congregates art and craft. The reason of this was transforming the design as a practice-based approach (Akbulut & Kesdi, 2017). The elements of design education and fine arts were combined. According to Ozsoy (2003), Bauhaus was the school, where the opportunity was provided to perform courageous experiments while using imagination considering design elements. Thanks to this course, students could evolve their knowledge and their special styles in terms of the discovering, creating and experimenting (Boucharenc, 2008).

Since the Gestalt theory appeared at the beginning of the 20^{th} century, design education was affected. Gestalt theory put forward the idea of pureness and easiness are must for design. Thanks to the Gestalt's approach to design, basic design education had turned to an intelligible and inclusive form.

2.3. Aspects of Basic Design

In 1951, Graves organized the elements of design in his book *The Art of Color and Design* that was considered as the reference book. He listed seven elements: line, direction, shape, size, texture, value and color. He also put forward the list of principles of design: repetition, alternation, harmony, gradation, contrast-opposition or conflict, dominance, unity and balance. Alheim (1954) published a study that takes strength from Gestalt approach. Thus, perceptual mechanism of visual art is covered with balance, shape, form, growth, space, light, color, movement, dynamics and expression. "All version of '*basic design*' rest ultimately on the belief that there exists what Gropius called the '*elements and laws of design*'. '*Elements*' of form and '*laws*' for putting them together." (Jones, 1969: 159). Jones (1969) also mentioned Kandinsky's description of elements. These are points, lines and planes for two-dimensional works. For three-dimensions, he describes elements as spheres, cones, cylinders, and pyramids. According to Jonas (1969), Moholy-Nagy added to this list some other elements as crystal, plate, strip, spiral. After that, Itten arranged them into this a list of materials, textures and, softness and roughness (Jones, 1969). Itten (1975) generally combines the idea of texture with tactile feelings. Students experienced different textures in Itten's preliminary courses. These materials were metal, wire, furs, bark, glass, fabrics, stone. Students learned creating contrast between their forms using different textures, tactile objects throughout the smoothrough, dull-shiny, transparent-opaque. They had tendency to increase their sense of touch and optical senses (Itten, 1975). For the interaction design foundation, pattern is defined as “patterns are simply a repetition of more than one design element working in concert with each other.” ("Repetition, Pattern, and Rhythm", 2018). Pattern is a repetition of any shape and it gives the sense of continuation.

Itten (1975) mentioned that people may have different approaches to basic design elements such as some of them tend to use light and dark, some of them use form, rhythm, color, proportions, others tend to use texture, spatial direction and volume. In addition to that, analyzed visual form parameters are point, line plane, texture, scale, color, pattern and contrast as the basic elements of the basic design (Dearstyne, 1986; Bonollo & Lewis, 1996). They were propounded by Bauhaus personalities as Itten, Moholy-Nagy, Kandinsky and Klee. Their aim is to release the creative powers of the student, to help him/her understand the nature of materials and discern the basic principles of creative work. Concern with style movements of any sort is consciously avoided. Observation and representation, to make clear the need for an identity of form and content, define the limits of the preliminary course (Bonollo & Lewis, 1996).

According to Itten (1975), form is the most important part of the preliminary course. Forms were described by expression of students who blend rhythms and its harmony. Basic geometric shapes, which is generally called as Euclidian geometry, is the primary expression of designers. That is why it is very easy to grasp, to learn the order, to depict (Denel, 1979). Zelanski and Fisher (1996) explain shape and form as two different things. They describe shape, which is related to a two-dimensional figure that appears. On the other hand, form is related to the three-dimensional figure that appears.

Color is a concept that shows the property of materials and also it serves the light of these materials (Agoston, 1987). In Bauhaus school, color is related to the surfaces especially for the three-dimensional designs. Colors reflect the quality of surfaces because they are related to the quality of appearance. Hue, intensity, texture influence each other as much as the material tactile or optical (Bayer, Gropius & Gropius, 1959). Itten (1975) mentioned about colors in his studies during he was teaching at Bauhaus school as a preliminary teacher. He first has been teaching primary colors, which are yellow, blue and red to his students. And then he let his students work with secondary colors which are orange, violet and green. After that, he was asking to the students to mix secondary colors to create tertiary colors which are yellow-orange, orange-red, red-violet, violet-blue, blue-green and green-yellow (Itten, 1975). He also categorized different contrast effects in the world of colors: The pure color (hue) contrast, the light-dark contrast, the cold-warm contrast, the complementary contrast, the simultaneous contrast, the contrast of quality (color saturation) and the contrast of quantity (Itten, 1975). Color and contrast have a role. This role was functionality as much as aesthetics (Dalke, Little, Niemman, Camgöz, Steadman, Hill & Scott, 2006: 343).

Furthermore, for design education especially basic design, there are aspects to combine all elements of design to create a design within a language as quality of design, characteristics of design and system of organizations. These aspects provided with design elements such as, color, contrast, pattern, texture, shape and form. In order to understand these aspects deeply, next section it will be explained.

2.3.1 Quality of Design

In order to understand the quality of design, unity, order, harmony, hierarchy, balance and rhythm terms will be defined in the context of basic design (Figure 1). These elements are common ground of basic design education. Therefore, students learn designing with the guidance of these elements.

Unity can define as being one in the organization. Harmony of elements in the organization attributes to order (Roth, 1993). Order is defined as “the way in which people or things are arranged, either in relation to one another or according to a particular characteristic” (Cambridge English Dictionary, 2018). Harmony is described as the pleasing of combinations and parts in between in a composition (Olguntürk & Demirkan, 2011). Hierarchy is a visual order which organizes design elements in a rank between importance and petty (Uysal Urey, 2017). Ching (2007:339) describe hierarchy as “the articulation of the importance or significance of a form or space by its size, shape, or placement relative to the other forms.” Balance provides visuals equilibrium. It depends among visual abundance, weights of the design elements. Unity and organization are the main organizations of balanced design. There are three types of balance as follows; symmetrical balance, asymmetrical balance and radial balance (Uysal Urey, 2017). Rhythm is the repetition or alternation of motifs or elements in the unifying movement (Ching, 2007).

Quality of design is the one of the aspects of design. Thanks to unity, order, harmony, hierarchy, balance and rhythm designers have evolved their design and projects. Therefore, it can be state that, quality of design of their projects should represent these elements in their design process.

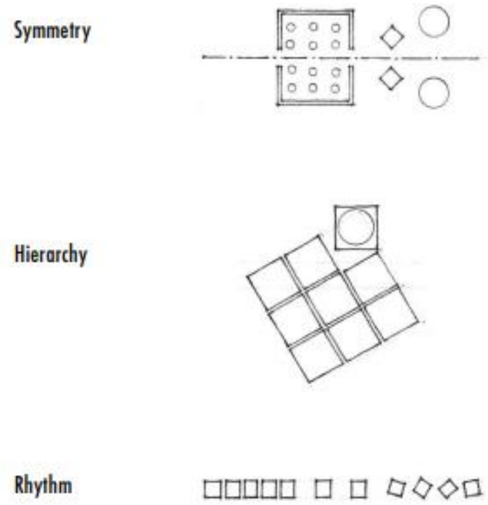


Figure 1: Quality of design elements. Reprinted from *Architecture Form, Space, & Order* (p.339), by F. Ching, 2007, Hoboken, N.J.: John Wiley & Sons.

2.3.2 Characteristics of Design

In order to understand the characteristics of design, shape, size/scale/proportion, direction/orientation terms will be described in the context of basic design (Figure 2). These elements are also essential for basic design education. Therefore, students learn designing with the supports of these elements.

Outlines and counter of an element represents the shape of this element. It is differentiated in regular and irregular shapes, and also its dimensions and sizes

(Ching, 2007; Olguntürk & Demirkan, 2011). Relative sizes between elements or shapes provides visual drama to take attention to in a single point or a focal point. It shows the relation and proximation between small and large as an element in the composition (Ching, 2007). Proportion joins in the size and scale as a degree, quantity or magnitude between elements (Olguntürk & Demirkan, 2011).

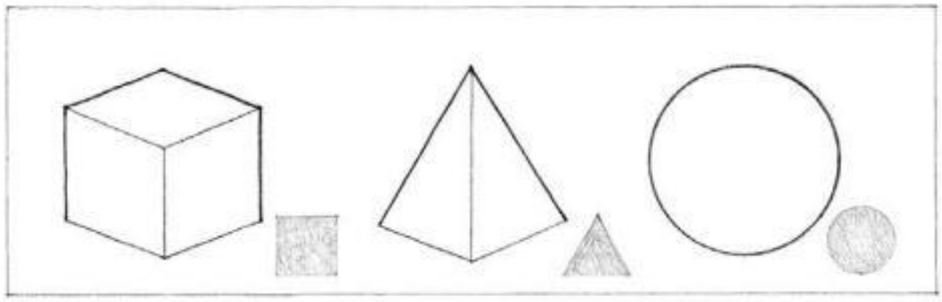
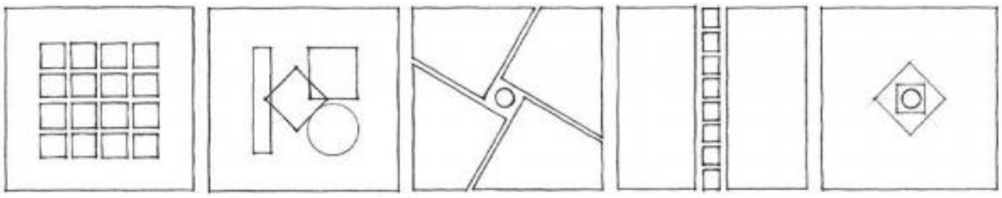


Figure 2: Shape/form/size. Reprinted from *Architecture Form, Space, & Order* (p.34), by F. Ching, 2007, Hoboken, N.J.: John Wiley & Sons.

2.3.3 Organization Systems

In order to understand the organization systems, central, axial, radial, linear, gridal and nodal terms will be described in the context of basic design (Figure 3). These systems are the base for basic design education. Therefore, students learn designing with the supports of these organization systems. Designers utilize from different system of organizations to create their projects. Central organization is one of them. It consists a center that is dominant, large or concentrated. It has secondary group/s around the center (Ching, 2007). But linear organizations are settled in a line and mostly they consist of repetitive forms which depends on size, form and function

(Ching, 2007). In addition to that, radial organizations combine both linear and central organizations' elements.



Grid Nodal Radial Linear Central

Figure 3: Organization systems, Reprinted from *Architecture Form, Space, & Order* (p.339), by F. Ching, 2007, Hoboken, N.J.: John Wiley & Sons.

It has one dominant center which directs several linear radials. On the other hand, nodes and nodal organization systems includes more than one centers. Around these centers, shapes or forms are distributed as a node (Ching, 2007).

2.4 Basic Design Thinking

2.4.1 Design Thinking and Abstraction

The critical issue in basic design education is abstraction. Students are trying to deal with an undefined goal and possible alternative appropriate solutions (Casakin & Goldschmidt, 1999). They have to learn how to deal with abstract compositions, rather than concrete products (Güngör, 2005). Therefore, they create and develop design languages by providing abstract compositions. In design education, ill-defined problems are given to students. According to Cross (2006), abstract problems, which are given at basic design courses, help students put forward their organized ideas about a design problem. Besides, learning by doing activity becomes the part of basic design education thanks to the process of studio activities.

2.4.2 Basic Design Problem Solving

In literature, there are various goal definitions for basic design education. These defined goals of basic design education are listed under the following categories: the development of creativity and problem-solving ability, the development of visual perception, and the development of design language (Beşgen et al., 2015; Denel, 1981; Kuloğlu & Asasoğlu, 2010; Lang, 1998; Makaklı & Özker, 2015; Özer, 2004; Salama & Wilkinson 2007).

Design means that an organization is proposed as a result or a solution to an existent problem. Lawson (1979) created a formulation for problem solving with architectural design students. He categorized problem solving activity in two groups; problem focused, and solution focused. These two are the bases for design problem solving. However, Dorst and Cross (2001) put forward the idea that solution and problem cannot be thought separately. Designers develop both in parallel. In order to put an idea to solve a problem, first attempt appears in the mind as form. After that, this form turns to real and concrete process of creation (Tunalı, 2004). This process is not linear because of abstraction. Therefore, to handle this process, logical and conscious steps must be taken with the help of reduction of complex abstraction to more concrete solutions.

As Çetinkaya (2011) said, students are managing a variety of exercises. Given projects and design problems proceed cumulatively therefore, students are expected to use their experiences that they gained in previous exercises. Within this knowledge, students have the tendency to be more practical to the framework of problem-solving. It is also expected from them to be enhanced in visual thinking, memory and understanding of their environment. In order to do that, they have to able to use different techniques of drawing and presentation. They have to be efficient at three-dimensional thinking as much as two-dimensional thinking and perception (Çetinkaya, 2011).

Basic design course contains two-dimensional and three-dimensional projects that deal with different types of design problems. Therefore, different types of approaches and ways of teaching design are used in basic design education. For two-dimensional projects, students use only paper materials to cope with a given design problem using design elements and principles, which are expected to be solved by students. For three-dimensional projects, it is expected as working with form relations, objects and its environments. In order to solve a design problem, students also integrate design elements and principles by using more three-dimensional materials such as polystyrene foam, corrugated cardboard, clay, plaster and wood (Erdoğdu, 2016; Makaklı & Özker, 2015; Resuloğlu, 2012).

Schön (1985) stated that design studio environment is very important for students to understand basics of design thinking, design action and theory of design. It is also an environment to courage 'learning by doing' activity. Basic design studio also aims to create a mathematical rationale in the problem-solving process, to encourage more connections to the outside world, to encourage decision-making skills and, more importantly, to improve themselves, within the framework of designing philosophy and theory (Hacıhasanoğlu, Hacıhasanoğlu & Emer, 2003). In the atmosphere of design studios, students have great opportunities to learn by doing the methods of design process as an intellectual movement (Durmuş Öztürk, Beşgen & Kuloğlu, 2018).

On the other hand, integrating digital tools in early stage design process provides students more meaningful influence in the outcome (Varınlıoğlu et al., 2015). When digital environments are included in the early stage design, students have tendency to participate to process more and to have more motivation to solve advanced problems. Therefore, it can be said that digital methods and tools provide students utilization.

CHAPTER III

VIRTUAL REALITY

3.1 Definition of Virtual Environment and Virtual Reality (VR)

Virtual environment (VE) is an experience with digital products. It is a spatial representation of 3D World, which allows real time interactions in different scenes. It is used as an agent for communicating with all processes of designing within the digital world (Bullinger, Bauer, Wenzel & Blach, 2010). It is a common medium among different industries such as automotive industry, medical industry and military industry. Especially on design research fields, various technologies like simulation tools are on the rise (Portman, et al., 2015). New virtual world platforms and technologies have aroused interests of researchers including design field. In addition to that VE have encouraged designers to represent and discover themselves with a great ease (Schnabel, Wang & Kvan, 2008).

There are various types of definition of virtual reality (VR). According to Cambridge Dictionary (2018), VR is “a set of images and sounds, produced by a computer, that seem to represent a place or a situation that a person can take part in” (Cambridge English Dictionary, 2018). Regenbrecht and Donath (1997) defined it as “the component of communication, which takes place in a computer-generated synthetic space and embeds humans as an integral part of the system…” (as cited in Portman, et al., 2015). According to Sherman and Judkins’s (1992), ‘take in part’ and ‘synthetic’ words, which are the parts of definitions of VR above, were explained by five i’s of VR. These i’s are intensive, interactive, immersive, illustrative and intuitive.

Biocca and Delenay (1995) explained VR as an experience, a world beyond reality (Berg &Vance, 2016), as digital technology, which includes “3D computer graphics, real time simulation techniques, and a wide array of input and output devices, powers interactivity, real time rendering and self-navigation (Erdoğan Ford, 2017) to create illusions of being in a virtual environment.” Furthermore, they put VR in three different categories. These are non-immersive, partially immersive and fully immersive. Within the content of this thesis fully, immersive reality is considered. In that point, immersive refers to “immerse the senses of the user. It is then able to update the environment in real time according to where the user is looking or moving.” (Biocca & Delenay, 1995:2). VR devices generate a virtual environment to replicate a real environment and present various experiences to users (Chryssolouris, Mavrikios, Fragos & Karabatsou, 2000). VR has changed the way computers are used in a way that processing big volume of abstract data, which is experiencing with touchable and visible features of virtual environment (Zhi-qiang, 2017).

Zhi-qiang (2017) also categorized VR into three aspects (immersion, interaction and imagination) to derive it from VE. Regarding to immersion, three-dimensional world is generated by computers and projection so that it can diversify a virtual environment when viewers immersed in the artificial environment, and they can sense the environment with this diversity (Zhi-qiang, 2017). Zhi-qiang (2017) explains the interaction as follows; in a virtual environment, user can change the direction, properties and motions of the objects like in a real world thereby they are able to manipulate the virtual environment as they wish. Imagination is defined as virtuality that encourages people to imagine, because it is the developed and it steps ahead of traditional drawings (Zhi-qiang, 2017).

3.1.1 Immersive Virtual Reality

Schnabel et al. (2008) said that the more virtual reality is immersive, the more designers have attitude to work interactively and three-dimensional with their media; movement and interaction are the definite parts of the creation process, which are reflections of the real world. Immersive visualization is what virtual reality really is. Virtual reality is a visualization technique, which has experienced a recent boom in professional and academic literature (Portman et al., 2015).

Presence is a sense of perception that person is feeling in the virtual world rather than the place where his/her own body really is (Sanchez- Vives & Slater, 2005). Immersion is very similar to the presence; immersion is when a person experienced as immersed in an environment that is through computer-controlled display systems. Computers are generating VR’s new three-dimensional interpretation environment and are constructing the three-dimensional spaces using graphics. Therefore, users are immersed in a virtualized three-dimensional world (Zhi-qiang, 2017).

3.1.2 Head Mounted Devices

Motion recognition algorithms and tracking systems enable natural body movements to be transformed into functional interaction techniques (Mitra & Acharya, 2007). The other device, which is a handheld controller, provides users' manipulation and navigation of objects in the virtual environment (Bowman, Coquillart, Froehlich, Hirose, Kitamura, Kiyokawa & Stuerzlinger, 2008). Different types of technologies display in different sizes that deliver information to people's senses; sight, hearing and touch, which are progressed during the last decade (Berg & Vance, 2016). VR technology commonly utilizes head-mounted displays (HDMs), audio displays; headphones, speakers or surround systems which are provided with sound localization and enable simulating sound as moving or coming from a specific point within a virtual environment; tracking systems; optical, magnetic, ultrasonic or inertial mediums that provide the positioning and orientation of physical objects within a virtual space in a synchronous time (Berg & Vance, 2016).

3.2 Virtual Reality in Architectural Design Problem Solving

Because of various benefits of technology, design education is affected in a positive way. One of the medium that becomes a part of design education is computer aided design. Computer aided design is based on a mathematical specification of shape (Leyton, 2001). According to Leyton (2001), people perceive shapes as a cluster and as differentiated deformations of primitive shapes. Baskinger (2008) pointed out that, computer aided design tools preserved traditional interfaces, thus it does not meet the need for responsiveness in early design.

Basic design education is the expression of the abilities in aesthetic level and transfer of thinking, emotions, and impressions of a person (Beşgen, et al., 2015). It raises awareness about visual sensitivity for transition between images and design fields. There are fundamental elements for basic design education. These are shape, form, color, contrast, pattern and texture. For the problem-solving activity in basic design, these elements are used to create a product of design. In order to create a product of design, design thinking and abstraction are the ways of the creation process. As a consequence, visual skills and three-dimensional perception should be used efficiently (Çetinkaya, 2011). In order to solve the design problem and to create a three-dimensional product, there are digital approaches to boost visual thinking and three-dimensional perception. This approach provides different opportunities that never exist in paper-based traditional environment (Oxman, 2008). Varınlıoğlu, Akçam and Halıcı (2015) supported this idea and stated that when digital environments are included in the early stage design students have tendency to participate to process more and much more motivation to solve advanced problems.

However, thanks to the achievements in technology and computer interfaces increased virtual reality more accessible for both complexity and price (Şener & Wormald, 2008). Increasing number of examples of VR use in design show that there is a strong potential for the architectural design (Portman et al., 2015). There are some examples below.

Ştefan (2012:1060) said "using VR spaces, students and teachers can work in an artificial re-created world in which understanding is mediated through an immersive multi-sensorial exploration". Researchers can manipulate variables while keeping design characteristics perpetual in virtual environment when they are working in VR spaces. Heydarian et al. (2015b) support this with the idea that virtual environment can reduce experimental noise thanks to differentiated features of perception in environment. Heydarian et al. (2015b) conducted a study which compared performance, perception and presence of participants. They used two environments - virtual and physical. Research indicated that participants act very similar in virtual office environment, which is provided by Oculus DK HDMs, and physical environment. Also, when they compare the immersive virtual environments (IVE) to other mediums as computer screens, they found IVE is a more realistic learning environment (2015a).

The immersive design tools have proven to be engaging, pleasurable and a good vector for the intention of designer (Rieuf, et al., 2017). Rief et al. (2017) also mentioned that participants found that immersive VR is simple and manageable, motivating, agreeable and pleasant. According to their study, results of the survey indicate that "immersive sketching tools empower the designer with a good ability to think and resolve space- related challenges." (Rief et al., 2017: 65). In addition to this, participants found VR experience more fun, pleasing and addictive and they accepted it enthusiastically, when compared to traditional method of sketching.

Cross (1999) affirmed that the reasoning process of the designer embraced connection between internal mental process and external expression where internal mental process and external expression appear in representation by sketches. In order to reflect this process, designers must have a medium which enables half formed ideas to be expressed and to be reflected upon: to be considered, revised, developed, rejected and returned to (Cross, 2010). VR technologies offer a new generation of CAD tools, which are promising media in terms of conceptual architectural design process (Rahimian & Ibrahim, 2011).

VR is the most recent and developing technology these days. However, “the more the activity encloses early stage design, like conceptual design, the less VR tools are developed and used” (Rieuf et al., 2016: 46), although it is the most powerful medium to get in touch with three-dimensional visual world. Ding, Liew, Maher, Gero and Drogemuller (2003) pointed out some benefits of 3D virtual worlds, which enable a design environment. The benefits that they explained are as follows: visualization of the building model, improvement of the value of shifting traditional 2D graphical representation towards real-time walkthrough and rendering, representation of multi-dimension design space, possibility to have multi-dimension design spaces by adding new components or linking various application packages and provision of real-time and multi-user interactions between the designer and the building model, designer and designer or among building objects.

A virtual building also has the potential of linking different databases and domain application models for the establishment of virtual multi-projects (Ding, et al., 2003). It may be linked to related information such as culture, history, environment and geography through the web when necessary. The study of Rahimian and Ibrahim (2011) focuses on the efficiency of VR in conceptual architectural design phase and they compare VR and traditional pen and paper sketching interfaces. They found that 3D sketching interface reduces the need for performing too many physical actions. While using 3D sketching, users perform more perceptual actions. Cognitive activities are significantly higher during 3D sessions rather than traditional sessions. “In 3D sketching design sessions, design team members shared design ideas more frequently than what they did in traditional design sessions.” (Rahimian & Ibrahim, 2011: 280).

3.3 Usability of Virtual Environment Systems

There is an increasing interest in industry in the use of VR (Berg & Vance, 2016). Whyte, Bouchlaghem , Thorpe and McCaffer (1999) conducted a research related to building industry which showed that VR could be useful, potentially. Mobach (2008) pointed out that designers and architects benefit from experiencing virtual reality before they construct. Squires and Preece (1999), Ardito, Costabile, Marsico, Lanzilotti, Levialdi, Roselli and Rossano (2006) and Deegan and Rothwell (2010) are some of the researchers who have been trying to close gaps in the literature in terms of usable learning applications as VR. In various fields, VR studies have been conducted and particularly in education industry, VR gains acceptance day by day but still it is insufficient (Chen, Lau & Teh, 2015).

New developing technologies such as VR and augmented reality (AR) provide foundation for research which concerns usability because these technologies are too young. Therefore, user-centered analysis is required for VR, which is developed by Oculus Rift, Samsung Gear and HTC Vive. In the root of the literature, it is found that the most crucial problem is experiencing cyber-sickness. It is the consequence of HDM VR. Cyber-sickness may cause the acceptance of the technology, performance and safety (DiZio & Lackner, 1997; Kennedy, Lilienthal, Berbaum, Baltzley, & McCauley, 1989; Regan & Price, 1994; Wilson, 1996).

3.3.1 International Organization for Standardization (ISO) Standards

The international organization for standardization (ISO) (1998) defined usability with standard 9241-11 as “the extent to which product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use” (ISO, 1998). ISO 9241-11 is the standard of ergonomics of human-system interaction. ISO made revision of standard of ISO 9241-11:1998 and now it is labeled as ISO 9241-11:2018. This standard provides a framework to understand usability. It also provides knowledge of applying this standard to situations where people experience interactive systems. According to ISO, this standard explains, “usability is an outcome of use”, defines “key terms and concepts, determine “the fundamentals of usability and clarify “the application of the concept of usability” (ISO, 2018).

Efficiency is defined by ISO (1998) as “the resources expanded in relation to the accuracy and completeness of goals achieved”. It is the resources that used up in the context of accuracy and completeness. Accuracy and completeness refer to achieved goals by users. It is responded to answer ‘Can you accomplish the task in an ideal timeframe and use of resources?’.

Effectiveness is defined by ISO (1998) as “the accuracy and completeness with which specified users can achieve specified goals in particular environments”. Effectiveness is measured as an answer of ‘Can you accomplish the task?’. The question is related to the goals or sub-goals of the user. Effectiveness is the accuracy and completeness of achieved goals (ISO, 2018).

Satisfaction is also defined by ISO (1998) as “the comfort and acceptability of the work system to its users and other people affected by its use.” Satisfaction measure answers this question ‘do you like the system?’ In order to extend this measure in a positive way, users should feel free from discomfort. This measure also extends user’s attitudes towards the use of the product.

Usability evaluation method (UEM) is proposed by Gray and Salzman (1998). UEM is a method generally used as a usability evaluation, which is testing to improve the usability of developmental stages of an interaction design (Hartson, Andre & Williges, 2009). Under the usability term, in heuristic evaluations, a prototype or any product is evaluated by individuals or teams (Nielsen & Molich, 1990; Nielsen, 1993). Using heuristic evaluations and usability tests together makes a design more useful, usable and desirable during the process of creation (Barnum, 2011). Barnum (2011) suggests using these two methods, heuristic evaluations and usability tests, together in order to reduce the bias of evidence. Revealing usability problems with a low-cost economy and limited time sources is the fundamental purpose of heuristic evaluations (Wilson, 2014). The tests are proper for evaluating existing systems or prototypes that need improvement.

Unger and Chandler (2012) agreed that qualitative and quantitative methods can be applied in usability tests. Unger and Chandler (2012) mentioned advantages of usability methods. The advantage of qualitative methods is that they are less expensive since limited participants are needed. On the other hand, quantitative methods generate results which can be controlled with statistical calculation for further studies.

3.3.2 Technology Acceptance Model (TAM)

Under the user satisfaction criteria within the usability context, there are various types of framework that indicate user experience with a technology as The Post-Study System Usability Questionnaire (PSSUQ) (IBM Design Center, 1992), Software Usability Measurement Inventory (SUMI) (Costalli, Marucci, Mori & Partenò, 2001), User Experience Questionnaire (UEQ) (UEQ, 2018), Software Usability Scale (SUS) (Brooke, 1996), and User Experience Model (UX) (Norman, 2004). Technology Acceptance Model (TAM) (Davis, Bagozzi & Warshaw, 1989) is one of the frameworks in user-based evaluations. TAM explains how the external features of the system affect the attitudes and perceptions that lead to the actual use of the system based on the theory of logical action (Balog & Pribeanu, 2009). According to authors, TAM explains the user's attitude towards the technology and the usage effects of that technology. This affection is proposed with two specifications; perceived usefulness and perceived ease of use, which are asserted by Davis (1989). Davis (1989:325) explains the aim of TAM is "to provide an explanation of the determinants of computer acceptance that is generally capable of explaining user behavior across a broad range of end-user computing technologies and user populations, while at the same time being both parsimonious and theoretically justified". In addition to that, TAM also includes other constructs such as intention to use and external variables. Venkatesh (2000) has proposed another construct to TAM - perceived enjoyment.

3.3.2.1 Perceived Usefulness

This component is described as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989:325). It is an approach and a perception of user. It explains how user approaches to technology and how this technology enhances performance and adaptation time of user. The level of user's approach affects usefulness (Balog & Pribeanu, 2009). Perceived usefulness has direct and positive effects on intention to use of any system. When user observes the system's positive outcomes, this outcome will boost to affect user's attitudes to using system and intention to use this system (Balog & Pribeanu, 2009). Perceived usefulness enhances users' job performance during the task completion in a system (Tenemaza, Ramirez & de Antonio, 2016).

3.3.2.2 Perceived Ease of Use

This component is explained as "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989:328). The more the system is effortless and easy, the more the degree of affection of user from their perception will increase in a positive way. Also, the system characteristics directly affect perceived ease of use (Balog & Pribeanu, 2009; van Raaij & Schepers, 2008; Yusoff, Zaman & Ahmad, 2011). Perceived ease of use decreases user's physical and mental effort (Tenemaza, et al., 2016). Perceived usefulness and perceived ease of use components are influenced by differentiated external variables and backgrounds such as level of education (Burton-Jones & Hubona 2005), gender (Venkatesh & Morris, 2000), or level of training in computer use (Venkatesh, 1999).

3.3.2.3 Intention to Use

This is defined as the level of intention of user to use actual system (Moon & Kim, 2001). According to Venkatesh and Davis (2000), perceived usefulness and perceived enjoyment affect intention to use of user. Authors define intention to use as "an individual's motivation or willingness to exert effort to perform the target behavior" (Davis, et al., 1989). Intention to use indicates the real use of the system (Abu-Dalbouh, Al-Buhairy & Al-Motiry, 2017). Furthermore, TAM supports that intention to use is related to the acceptance of technology which is also determined by perceived usefulness and perceived ease of use (Davis & Venkatesh, 2000) (Figure 4).

3.3.2.4 Perceived Enjoyment

This component is also defined as "the extent to which the activity of using a specific system is perceived to be enjoyable in its own rights, aside from any performance consequences resulting from system use" (Venkatesh, 2000). Motivation is the most important base of perceived enjoyment. Authors also add that when considering education and technology, young learners are part of this therefore enjoy is inevitable to think motivation (Balog & Pribeanu, 2009). When user believes or experiences positive outcomes of the system, it affects directly and positively user’s intention to use this system.

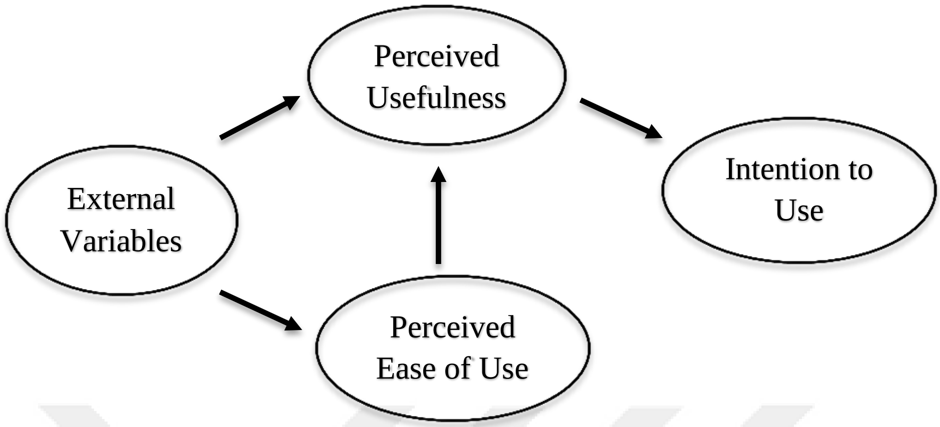


Figure 4. TAM framework. Adapted from "User acceptance of computer technology: A comparison of two theoretical models" by F., D. Davis, R., P. Bagozzi and P., R. Warshaw, 1989, *Management Science,* 35, 982-1003.

CHAPTER IV

METHODOLOGY

4.1. Research Question and Hypotheses

One research question was formulated for this thesis. The research question of this thesis is as follows:

> Can virtual reality adequately support problem solving activity of basic design education?

In response to this research question, six hypotheses and twelve sub-hypotheses are formulated. The hypotheses are as follows:

H1: There is a statistically significant usability of VR difference between groups in terms of four components of TAM.

H1a: There is a statistically significant usability of VR difference between groups based on the VPU during problem-solving activity.

H1b: There is a statistically significant usability of VR difference between groups based on the VPEO during problem-solving activity.

H1c: There is a statistically significant usability of VR difference between groups based on the VIU during problem solving activity.

H1d: There is a statistically significant usability of VR difference between groups based on the VPE during problem solving activity.

H2: There is a statistically significant usability of paper-based environment differences between groups in terms of four components of TAM.

H2a: There is a statistically significant usability of paper-based environment difference between groups based on the PPU during problem solving activity.

H2b: There is a statistically significant usability of paper-based environment difference between groups based on the PPEO during problem solving activity.

H2c: There is a statistically significant usability of paper-based environment difference between groups based on the PIU during problem solving activity.

H2d: There is a statistically significant usability of paper-based environment difference between groups based on the PPE during problem solving activity.

H3: There is a statistically significant difference within groups in terms of four components of TAM.

H3a: There is a statistically significant PU difference between VR and Paper-based environment during problem solving activity.

H3b: There is a statistically significant PEU difference between VR and Paper-based environment during problem solving activity.

H3c: There is a statistically significant IU difference between VR and Paper-based environment during problem solving activity.

H3d: There is a statistically significant PE difference between VR and Paper-based environment during problem solving activity.

H4: There is a statistically significant effectiveness difference between VR and paper-based environment in paper-based group.

H5: There is a statistically significant effectiveness difference between VR and paper-based environment in VR group.

H6: There is a statistically significant effectiveness difference between VR and paper-based groups during problem solving activity.

4.2 Method of the Experimental Study

4.2.1 The Setting and Participants

With regard to understand the usability of VR in basic design education, the experimental study is conducted in the Basic Design courses. These courses are given during 2017-2018 Spring Semester under the names of ‘FA 101 Basic Design I’ and ‘FA 102 Basic Design II’ for first year undergraduate students studying interior architecture, architecture and landscape architecture Departments in Bilkent University. The experimental study was conducted in two settings. VR-based group generated the experiments in the computer laboratory of the department, whereas the paper-based group did experiments in the studio environment. All the participants solved VR problems individually and, each problem took approximately two and a half hours for each participant.

According to Nielsen and Landauer (1993), at least 15 participants or users provide discovering for usability problems. Within the framework of this thesis, a total of 20 first year undergraduate students from the Department of Interior Architecture and Environmental Design and Department of Architecture were chosen voluntarily. Participants who experienced motion-sickness and claustrophobia were not admitted to the experiment. After they informed about motion-sickness and claustrophobia, they signed consensus form to agree that they attended to experiment voluntarily. All participants are first year students who did not take any detailed digital media courses in their departments. Therefore, it is assumed that twenty participants had acquired the same amount of knowledge and experience in CAD. The sample group of this thesis was divided equally into two problem setting groups (Figure 5). Each group has 10 participants with an age range between 18 to 21 years and with a mean age of 19.2. In order to avoid any biases, the order of the given problems was changed as illustrated in Figure 5. One of the groups named as VR-based group has 6 female and 4 male participants, the other group named as Paper-based group has 8 female and 2 male participants. Participants were chosen randomly for each created group.

VR-based group solved two VR problems and one paper-based problem while paper-based group solved one VR problem and two paper-based problems. VR problem required VRE and HMD to solve given design problems. Paper-based problem required traditional problem-solving methods and materials as paper, glue, and cardboards.

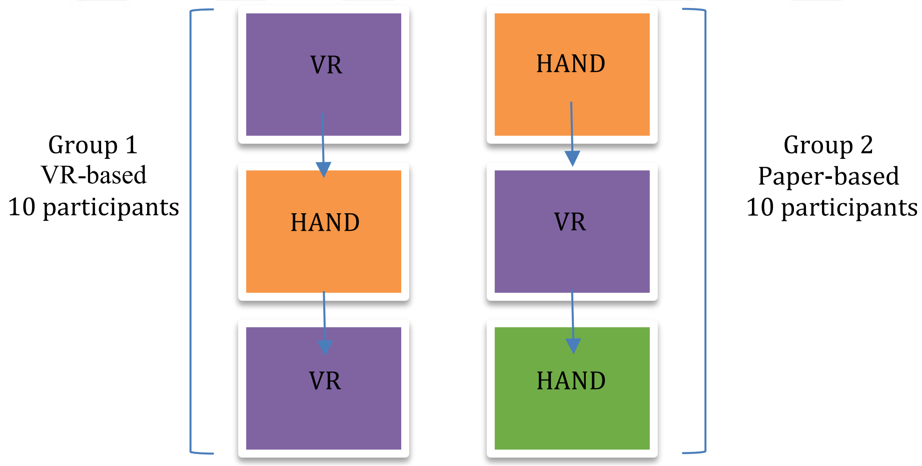


Figure 5. Participants and group distribution, drawn by the author, 2018.

4.2.2 Procedure

The experimental study was conducted between the dates of 8 March 2018 and 16 April 2018. Both groups attended the experiments on each Monday and Thursday because basic design courses were held in these days of the week. Before the experiment participants were informed about motion-sickness and claustrophobia and asked them if they feel any of it, they informed the lab assistant immediately.

The procedure was composed of five phases for each group (Figure 6). For VR based group, in the first stage, which is phase A, there were eight tasks in virtual reality environment. Regarding VR-based group, in the first task, participants read the VR design problem (See Appendix A1) and wore the VR tool of Oculus Rift DK2 HMDs on their head and hands (Figure 7). Then, they finished the setup of the VR tool according to their height and space that they were using for walking and moving their hands. In the third task, they conducted a general demo trial of the tool which showed how to use, control and manage HDMs and its tools. In the fourth task, they did the demo trials of the Google Blocks software, which is used for solving the design problem. In this demo, they learned how to use the VR tool along with the design using the software application. As the fifth task, participants solved their given design problem. Sixth and seventh tasks were saving their projects on www.poly.google.com website and writing their description about their project, and then they published it. In the final task, after they published their projects on website, they filled the Presence Test Questionnaire (See Appendix B1) as eighth task.

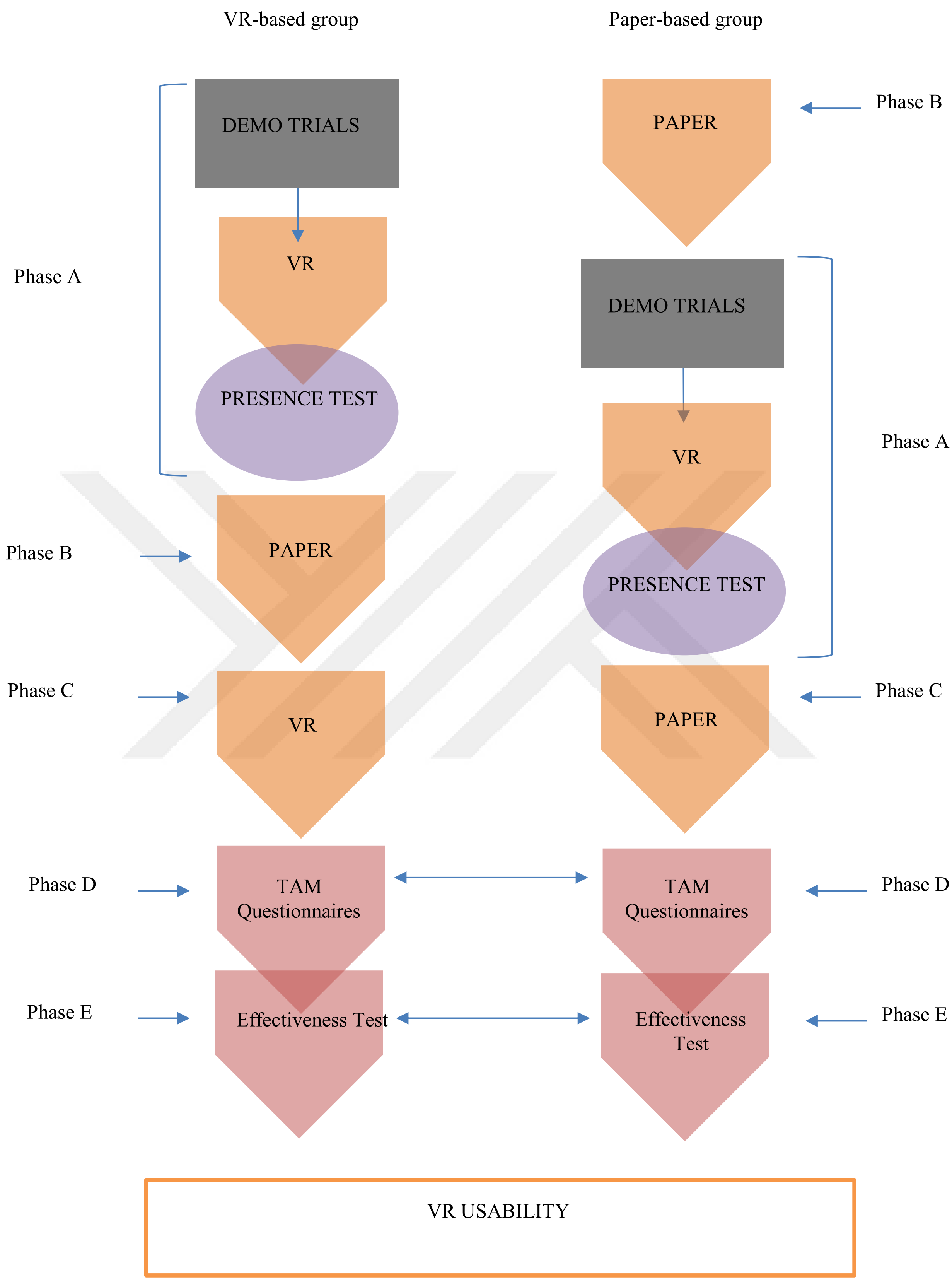


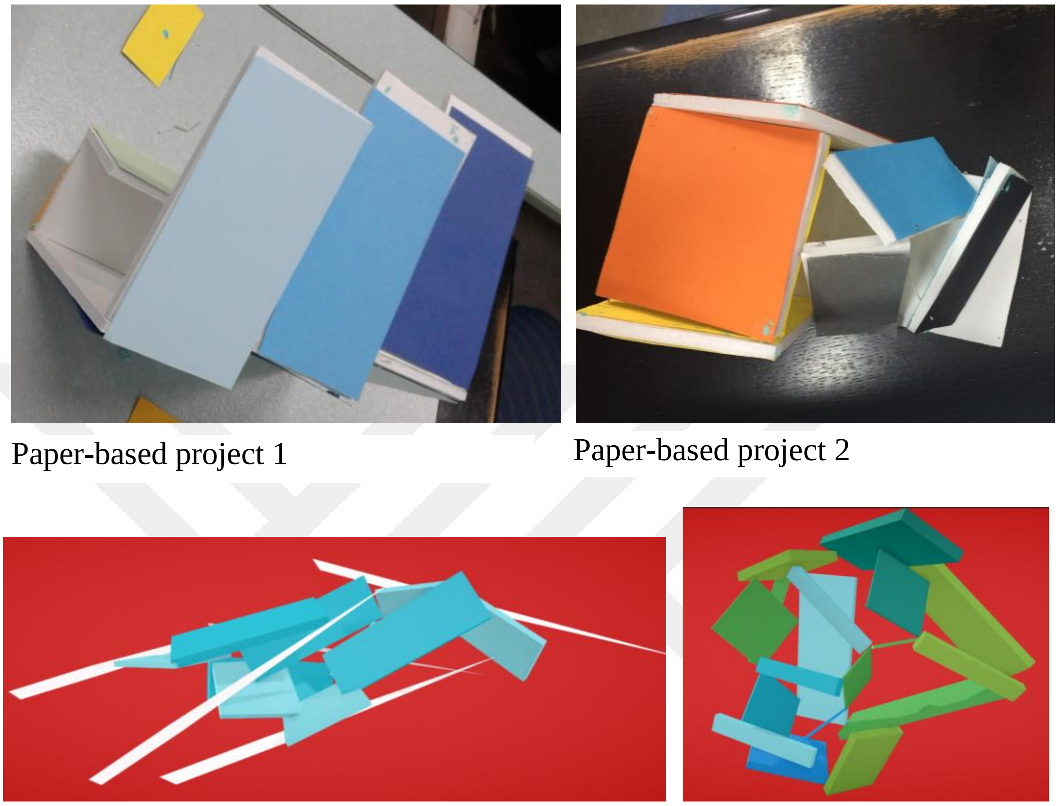
Figure 6. Theoretical framework of the research, drawn by the author, 2018.

Second stage of the VR-based group, which is phase B, was designing in a paper-based environment. In this phase, there are three tasks. In the first task, participants read the paper-based design problem (See Appendix A2). In the second task, they started to design their project with traditional materials and methods. Materials were given readymade to them (Figure 8). There were several shapes that are expected in the design problem. Square cardboards, rectangle cardboards, linear elements,

Figure 7. VR environment setting

Figure 8. Paper-based environment setting

colored papers, glue and nails, blank papers, pens and eraser were the given materials. In the third task, after participants finished their projects (Figure 9), it was expected to explain their design by writing on given papers.



Paper-based project 1

Paper-based project 2

VR project 1

VR project 2

Figure 9. Projects designed by participants

Third stage, which is phase C, was again designing in the VR environment (Figure 7) To eliminate the learning effect, the design problem was given differently compared to phase 1, by changing the given shapes. In phase C, firstly, participants read VR design problem (See Appendix A3), wore HMDs on their head and hands, and solved given design problem on VRE. Then, they saved their projects on www.poly.google.com website, wrote their description about their project and published it. In the fourth stage, which is phase D, Technology Acceptance

Measurement (TAM) questionnaire was conducted (See Appendix B2 and B3) and finally stage 5, which is phase E, was effectiveness test (See Appendix B5).

There were also five phases in the paper-based group. The content of the phases was same as the phases in VR-based group. To eliminate the order effect, only the order of the phases was changed. The paper-based group started with phase B of the VR-based group, which was designing in a paper-based environment.
Then, the group and fifth stages, which are phase D and E, were again TAM and effectiveness test.

4.3 Instruments

4.3.1 Questionnaires

The questionnaires, which were conducted by participants, were TAM for VR, TAM for paper-based, Presence Test (PT) and Technology Familiarity Test (TFT). There was also an effectiveness test, which was conducted by the two course instructors to evaluate the success of design solutions based on the three following criteria: (1) qualities of design based on unity, order, harmony, hierarchy, balance, rhythm; (2) characteristics of design elements based on shape, size, scale, proportion, direction, orientation; and (3) system of organization based being central, axial, radial, linear, gridal, nodal, multi-nodal. Instructors gave a score for each item out of 10. At the end, total scores of items were calculated to find the effectiveness value of design solutions.

When questionnaires were composed, a large number of studies were reviewed extensively. TAM questions were selected from different researches (Chesney, 2006; Davis, 1989; 1993; Davis, et. al, 1989; Hsu & Lu, 2004; Van Raaij & Schepers, 2008; Venkatesh, 2000; Venkatesh, Morris, Davis & Davis, 2003) to develop an adapted TAM model for VR and paper-based settings. They were adapted according to the content of studies and experiments. It was originated by Davis' studies in 1989 and 1993. TAM includes 20 questions for each model. These questions were divided into four categories: (1) perceived usefulness; (2) perceived ease of use; (3) intention to use, and (4) perceived enjoyment.

Presence Test was adapted from the study of Witmer & Singer (1998). It is the experience of feeling and being in an environment. When virtual environments are considered, presence refers to experiencing the artificial computer-generated environment. Witmer and Singer (1998) analyzed deeply the degrees of presence. These degrees are focus (Fontaine, 1992), involvement, immersion and presence. Sheridan (1992) stated that subjective reports are the essential basic measurements for presence. However, Witmer and Singer (1998) states that strength of presence can differ in terms of the characteristics of virtual environments to be practiced. Thus, the author created a presence questionnaire based on the self-reports of users. In order to analyze the presence of users to measure with presence questionnaire, the involvement factor is considered for this thesis; questions based on 5-point scale from compelling to not compelling.

Technology familiarity test (TFT) is a questionnaire that comes from literature (O'Brien, Kelly, Lehane, Livingstone, Cotter & Butt, 2015). There are different types of TFT and they were generally composed according to content of researches. However, questions were obliviously similar, just the devices were differentiated in terms of context. Thus, because of VR is the main context of this research, devices that are related to VR were chosen for questionnaires. After that, it was asked that which device/s they used, how much they used these devices and how often (Swiss Federal Institute of Technology, 2018).

4.3.2 Tools

The virtual reality head mounted device used for this thesis was a high tech visual product, Oculus Rift DK 2, which is one of the most developed technological devices among the branches, such as Google, HTC and Sony. Oculus Rift DK 2 is used with a head mounted glasses, 2 sensors and 2 hand touch controllers (Figure 10). It is developed by Google. Google provides online market that has various applications for Oculus. Within the context of this thesis, Google Blocks software application was chosen to design and create shapes in the VR-based environment. It is a Google-based application on the VR market, which can be downloaded for free. It has different commands to create regular and irregular shapes that can be moved, turned and rotated in every directions, and can be colored. These characteristics of the software application make the software application appropriate for basic design problems.

Figure 10. Oculus DK2 tools, https://www.oculus.com/rift/#oui-csl-rift-games=mages-tale, 2018

CHAPTER V

RESULTS & DISCUSSIONS

5.1 Descriptive Analysis Results of Usability of Virtual Reality

In this chapter of the thesis, firstly it will be explained participants' technology familiarity, secondly homogeneity of groups will be demonstrated, then presence test results will be explained, further reliability of the tests will be indicated, finally descriptive analysis will have explained.

First of all, among the twenty participants, seven of them were familiar with digital design methods, such as AutoCAD. According to the information given in the TFT, only one participant was not familiar with current technologies such as tablets and VR environments. Only one participant was very familiar with VR technologies and five participants fairly familiar with VR technologies. All of them spend more than ten hours a week with computer and the Internet. Sixteen participants have been using computer and Internet more than five years. Three participants did not take the TFT.

In order to understand homogeneity of sample groups, basic design course grades of participants were analyzed, in order to indicate that, independent samples t test was applied, and it is found that there is not any statistically significant difference between VR and paper-based groups in terms of success ($t=0.935$ $df=18$, $p=0181$). Therefore, it can be stated that, both groups were divided into similar in terms of the success of basic design.

Furthermore, in order to understand how participant felt involve in VR, presence test survey was conducted. The result of the presence test survey shows that participants largely involved the VR ($M=3.84$, $SD=0.349$). Therefore, participants felt fully immersed during problem-solving activity in VR.

Moreover, the reliability of questionnaires is tested. In order to indicate reliability, Cronbach's alpha value was considered. Twenty questions of TAM questions for VR was tested. For an internal consistency, it is put forward the idea that the Cronbach's alpha value should be higher the value of 0.7 (Nunnally, 1978). Reliability test for TAM for VR was analyzed, and in this experimental study the Cronbach's alpha value was found 0.89. This result shows that the test was reliable.
In addition to that, Reliability is tested for twenty questions of TAM for paper-based and in this experimental study, the Cronbach's alpha value was found 0.83. Therefore, it is demonstrated that the test was reliable. In addition to that, components of both TAM questionnaires are analyzed separately in terms of perceived usefulness, perceived ease of use, intention to use and perceived enjoyment (Table 1).

Table 1. TAM shortened titles

TAM Components		**Paper-based**	**VR**
Perceived Usefulness	PU	PPU	VPU
Perceived Ease of use	PEU	PPEU	VPEU
Intention to Use	IU	PIU	VIU
Perceived Enjoyment	PE	PPE	VPE

Table 2. Mean comparison between groups.

Categories of Questions	**Paper Group Mean Values**	**VR Group Mean Values**
PPU	3.167	3.366
PPEU	3.451	3.568
PIU	3.399	3.294
PPE	3.48	3.3
VPU	3.583	3.501
VPEU	3.351	3.266
VIU	4.234	3.634
VPE	4.66	4.74

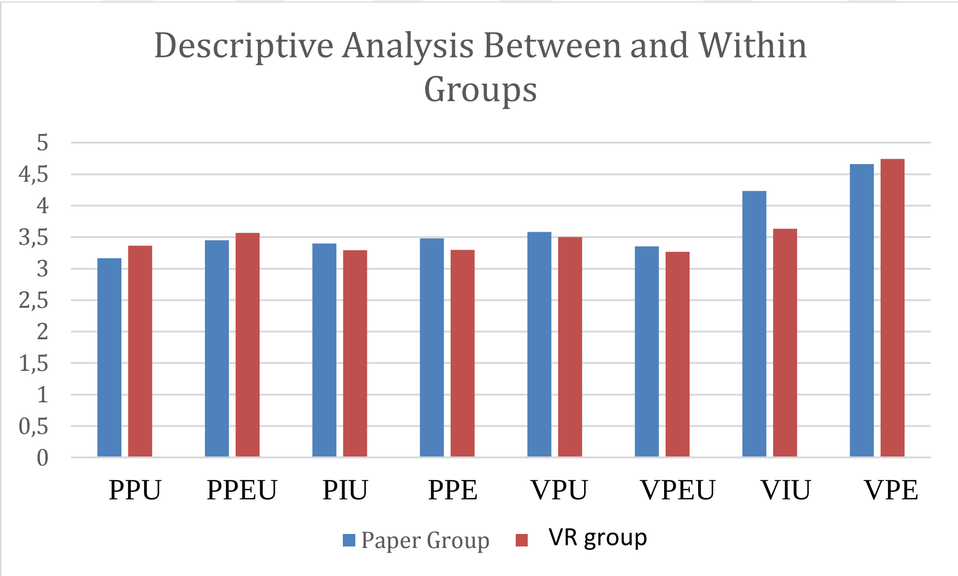


Figure 11. Usability comparison between VR and paper-based groups.

According to the mean differences between TAM for paper-based and TAM for VR questionnaires, paper and VR groups found VR usable which is shown at Table 2 and Figure 11. Except the sub-category, which is ‘perceived ease of use’ was found less valuable in VR (M=3.35 for paper group, M=3,27 for VR group) than paper-based environment for both groups (M=3.45 for paper group M=3.57 VR group).

5.2 Comparison Analysis of Usability of Virtual Reality

5.2.1 Effectiveness Findings

In order to measure usability of any product, ISO defined effectiveness, efficiency and satisfaction (1998). According to ISO 9241-11:2018 (2018) ergonomics of human-system interaction, measures for the components of effectiveness are task completeness, objectives achievement, errors in task. Therefore, in order to measure effectiveness of design products, two experts evaluated the project that participants designed in both VR and paper-based environments.

Table 3. Effectiveness of the environments

	Mean Values	
Problems	**VR Group**	**Paper Group**
VR Problem 1	19.18	19.51
VR Problem 2	21.50	
Paper Problem 1	18.41	21.15
Paper Problem 2		20.81

From the results, it is indicated that in Table 3, design products of VR group are effective in VR (M=21.50 for VR problem 2) and design products of paper group are also effective in paper-based environment (M=21.15 for paper problem 1, M=20.81 for paper problem 2).

In order to indicate statistically effectiveness difference of VR and paper-based environment in groups separately, one sample t test was conducted. According to one sample t test, when paper-based group was considered only, it is found that there is a statistically effectiveness difference between paper-based environment (t=21.745 df=0 p=0.000) and VR (t=17.177 df=9 p=0.000).

When VR group was considered only, it is found that there is a statistically effectiveness difference between paper-based environment (t=12.725 df=9 p=0.000) and VR (t=22.638 df=9 p=0.000). As a result of tests, “H4: There is a statistically effectiveness difference between VR and paper-based environment in paper-based group.” and “H5: There is a statistically effectiveness difference between VR and paper-based environment in VR group.” are not rejected.

In order to analyze the statistically effectiveness difference between VR group and paper-based group in terms of VR and paper-based environment, paired samples t test was also conducted. According to the test there is a statistically effectiveness difference between VR and paper-based environment between VR and paper-based groups (t=1.945 df=9 p=0.042). As a result of that “H6: There is a statistically significant effectiveness difference between VR and paper-based groups during problem solving activity.” is not rejected.

5.2.2 Technology Acceptance Model Findings

All the metrics of TAM questionnaires were statistically analyzed in order to assess the usability of the systems. TAM was studied in experiment within two groups; VR and paper. In addition to that, TAM questionnaires were separated into two; TAM for VR, TAM for paper-based environment. Therefore, two groups and two TAMs were integrated for this experimental study (Figure 12).

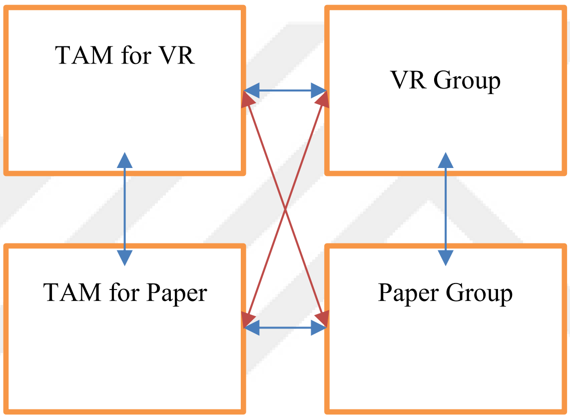


Figure 12. Test distribution between and within groups

5.2.2.1 Independent Samples T Test

In order to indicate whether there is a significant difference between VR-based and paper-based groups in terms usability of VR, t-test was conducted. Results of the independent samples t-test show that there is not any statistically significant difference between groups in TAM for VR regarding VPU, VPEO, VIU, VPE. Regarding to the results it can be said that H1: There is a statistically significant VR differences between groups in terms of four components of TAM is rejected. In Table 4, all results are shown.

Table 4. VR analysis between groups in terms of four components of TAM

	t	df	P
VPU	0.568	18	0.288
VPEU	0.323	18	0.375
VIU	1.598	18	0.063
VPE	-0.475	18	0.32

In order to indicate whether there is a significant difference between VR-based and paper-based groups to consider usability of paper-based environment, an independent samples t-test was also conducted. Results of the independent samples t-test show that there is not any statistically significant difference between groups in TAM for paper-based environment regarding PPU, PPEO, PIU, PPE. Regarding to the results, it can be said that H2: There is a statistically significant paper-based environment differences between groups in terms of four components of TAM.
is rejected. In Table 5, all results are shown.

Table 5. Paper-based environment analysis between groups in terms of four components of TAM

	t	df	P
PPU	-0.466	18	0.32
PPEU	-0.300	18	0.383
PIU	0.014	18	0.494
PPE	0.372	18	0.357

5.2.2.2 Paired Samples T Test

In order to indicate whether there is a significant difference between VR and paper-based environment to consider TAM, paired sample test was conducted. According to the paired samples t test, it is found that there is not any statistically significant difference between PPU and VPU (t=-1.057, df=19, p=0.152), (PPU M=3.2665, SD=.935448, VPU M=3.6, SD=.76491). Therefore, regarding the results, it can be said that “H3a: There is a statistically significant PU difference between VR and Paper-based environment.” is rejected. According to the paired samples t test, it is found that there is not any statistically significant difference between PPEU and VPE (t=0.923 df=19, p=0.368), (PPEU M=3.3095, SD=.85013, VPEU M=3.3085, SD=.57456). Therefore, regarding the result it can be said that “H3b: There is a statistically significant PEU difference between VR and Paper-based environment.” is rejected.

According to the paired samples t test, it is found that there is a statistically significant difference between PIU and VIU (t=-1.820, df=19, p=0.0425), (PIU M=3.3995, SD=.76419, VIU M=3.8840, SD=.72757). Therefore, regarding the result, “H3c: There is a statistically significant IU difference between VR and Paper-based environment.” is not rejected. All results are shown at Table 9.

According to the paired samples t test, it is found that there is a statistically significant difference between PPE and VPE (t=-5.331, df=19, p=0.000), (PPE M=3.39, SD=1.05726, VPE M=4.69, SD=.49101). Therefore, regarding the result, “H3d: There is a statistically significant PE difference between VR and Paper-based environment.” is not rejected. All results are shown at Table 6.

Table 6. Comparison analysis within groups in terms of four components of TAM

	t	df	P
PPU-VPU	-1,057	19	0.152
PPEU-VPEU	0.923	19	0.368
PIU-VIU	-1.820	19	**0.0425**
PPE-VPE	-5.331	19	**0.000**

5.2.2.3 Correlation and Regression Analysis

In this chapter of the experimental study, correlation among components of TAMs will be analyzed. Pearson Correlation Coefficient measures the relational numerical data between two sets of value or scores ranges between -1 to 1 (Howitt & Camer, 1999). Since the data is ranked, Spearman's rho was implemented to given statements to TAM questions. Therefore, it can be understood the degree of relationship with analyzing correlation scores. According to Howitt and Cramer (1999), values between -1 and 1 shows the degree of relationships. For instance, a correlation points of 1.00 shows that there is a positive perfect association between variables whereas -0.5 shows negative moderate relationship between variables.

Venkatesh and Davis (2000) proposed a theoretical framework for the determinants of TAM. According to framework there is a relation between perceived usefulness and perceived ease of use, perceived usefulness and intention to use, perceived usefulness and perceived ease of use. Therefore, in this experimental research, the relation between TAM items (Table 7) (PU, PEU, IU, PE) were studied statistically for both environment (VR-based and paper-based).

Table 7. TAM items distribution

TAM Items	Questions
PU	q1 q2 q3 q4 q5 q6
PEU	q7 q8 q9 q10 q11 q12
IU	q13 q14 q15
PE	q16 q17 q18 q19 q20

Table 8. Correlation results in TAM for VR

Spearman's rho	q1 VR enables me to accomplish task more quickly	q3 VR makes it easier to do my job	q4 VR has improved my productivity	q6 VR enhance my effectiveness on the job	q13 I intend to use any system using VR when it becomes available in basic design courses	q14 Assuming I had access to the VR, I intend to use it	q17 System is pleasant	q18 Feel enjoyment
q1 VR enables me to accomplish task more quickly	1				0.631			
q3 VR makes it easier to do my job		1			0.681			
q4 VR has improved my productivity			1		0.532			
q6 VR enhance my effectiveness on the job				1	0.597	0.590	0.882	0.501
q13 I intend to use any system using VR when it becomes available in basic design courses					1			
q14 Assuming I had access to the VR, I intend to use it						1		
q17 System is pleasant							1	
q18 Feel enjoyment								1

Table 9. Correlation results in TAM for paper-based

Spearman's rho	q1 Paper-based tools enables me to accomplish task more quickly	q4 Paper-based tools have improved my productivity	*q6 Paper-based tools enhance my effectiveness on the job*	q17 System is pleasant
q1 Paper-based tools enables me to accomplish task more quickly	1			0.523
q4 Paper-based tools have improved my productivity		1		0.612
q6 Paper-based tools enhance my effectiveness on the job			1	0.0545
q17 System is pleasant				1

In this part, TAM for VR questionnaire will be explained. When compered IU and PU items it is found that there is positive moderate correlation between q1 and q13. Given answers to '*Virtual reality enables me to accomplish task more quickly' (q1)* is correlated with the given answers to *'I intend to use any system using virtual reality when it becomes available in basic design courses'(q13)* (r=0.631 p=0.003). In the context of same item comparison, there is also positive moderate correlation between q3 and q13. Given answers to *'Virtual reality makes it easier to do my job' (q3)* is correlated with the given answers to *'I intend to use any system using virtual reality when it becomes available in basic design courses' (q13)* (r=0.681 p=0.001). In addition to that, there is positive moderate correlation between q4 and q13. Given answers to *'Virtual reality has improved my productivity' (q4)* is correlated with the given answers to *'I intend to use any system using virtual reality when it becomes available in basic design courses' (q14)* (r=0.523 p=0.018). There is positive moderate correlation between q6 and q14. Given answers to *'VR tools enhance my effectiveness on the job' (q6)* is correlated with the given answers to *'Assuming I had access to the VR, I intend to use it' (q14)* (r=0.590, p=0.005). Thereby it should be said that, perceived usefulness and intention to use are correlated in this experimental research (Table 8).

On the other hand, in this experimental research, the correlation between PU and PE is found that there is strong positive correlation between q6 and q17. Given answers to *'VR tools enhance my effectiveness on the job' (q6)* is correlated with given answers to '*System is pleasant'(q17)* (r=0.882 p=0.000). There is also moderate positive correlation between q6 and q18. Given answers to '*VR tools enhance my* *effectiveness on the job' (q6)* is correlated with given answers to *'Feel enjoyment' (q18)* (r=0.501, p=0.024) (Table 8).

In this part, TAM for paper is also analyzed. When TAM for paper questionnaire is analyzed, based on the comparisons among PU and PEO, PU and IU, PU and PE, it was found that there is only significant correlation between PU and PE. Therefore, it is found that there is positive moderate correlation between q1 and q17. Given answers to *'Paper-based tools enables me to accomplish task more quickly' (q1)* is correlated with the given answers to '*System is pleasant' (q17)* (r=0.523, p=0.004). There is also positive moderate correlation between q4 and q17 (r=0.612, p=0.013); q6 and q17 (r=.0.545, p=0.013). Given answers to *'Paper-based tools have improved my productivity' (q4)* is correlated with the given answers to '*System is pleasant'(q17)* and given answers to '*Paper-based tools enhance my effectiveness on the job'(q6)* is correlated with the given answers to '*System is pleasant'(q17).* Therefore, it should be said that there is a significant correlation between perceived usefulness and perceived enjoyment in terms of TAM for paper-based (Table 9).

Table 10. Multiple regression analysis between questions

q3	R	F	P
q5	0.711	18.404	0.000**
q13	0.837	19.953	0.000**
q9	0.884	18.975	0.000**

There are statistically significant regressions only in TAM for VR. These are between q6 and q17 p=0.068 R square=0.173 F=3.77, q6 and q18 p=0.024 R square=0.251 F=6.027. Based on the regression analysis, there are also statistically significant regression values between q3 (dependent) and q5, q13, 19 (independents). In order to indicate predictors of q3 multiple stepwise regression was applied (Table 10).

5.4 Overall Discussion of the Findings

In this thesis, VR in basic design education was researched to assess usability which depends on the ISO standards and TAM. It was aiming to find VR whether supports or not the problem-solving activity of basic design education. In literature, VR was investigated and searched with the differentiated methods. However, this experimental study is the new approach and perception for the VR which is included in different concepts as usability and basic design education. According to the experimental study of this thesis, the statistical results of the study showed that there is no significant difference in terms of usefulness and easiness between VR and paper-based tools. However, there are significant differences in terms of enjoyment and intention to use between VR and paper-based environments. When compared the mean values of VR and paper-based environments, it can be stated that participants found VR more enjoyable and intentional to use. When explaining the mean differences between the groups in terms of four aspects of TAM, which are usefulness, easiness, intentional use and enjoyment, paper-based group found VR more useful, easy to use and intentional to use (Table 11).

Table 11. Overall result of experimental study

Results	Evidence
VR is found more effective than paper-based environment when compared VR group and paper-based group.	Table 3 and page 48
There is not any statistically TAM for VR difference between VR and paper-based groups	Table 4
There is not any statistically TAM for paper-based environment difference between VR and paper-based groups	Table 5
There is not any statistically perceived usefulness difference within groups (regarding PPU-VPU)	Table 6
There is not any statistically perceived ease of use difference within groups (regarding PPEU-VPEU)	Table 6
There is a statistically intention to use difference within groups (regarding PIU-VIU)	Table 6
There is a statistically perceived enjoyment difference within groups (regarding PPE-VPE)	Table 6
There is a positive correlation between VPU and VIU	Table 8
There is a positive correlation between VPU and VPE	Table 8
There is a positive correlation between PPU and PE	Table 9
Predictors of q6 *'Virtual reality enhances my effectiveness on the job'* are q17 '*System is pleasant'* and q18 '*Feel enjoyment'* separately.	Chapter 5.2.2.3
Predictors of q3 '*Virtual reality makes it easier to do my job'* are q5 '*Virtual reality gives me greater control over my job'*, q13 *'I intend to use any system using virtual reality when it becomes available in basic design courses'* and q19 *'I would like to repeat same experience'*.	Table 10 Multiple regression analysis

The reason for that could be the attractiveness of the technology. They might be bored with traditional media compared to VR technologies, which is more attractive for young population (Venkantesh, 2000). As Çetinkaya (2011) said, students have to be more practical to the problem-solving while they are enhancing their visual thinking efficiency in the three-dimensional visions. So VR environments could be seemed more practical and enhancing their visual thinking ability to solve their problems.

When Schön's (1985) statement of 'learning by doing' is considered, which is very important for basic design education, experiences with traditional methods could be more supportive for ‘doing’ activities. However, Heydarian et al. (2015b), found that immersive virtual environments provide people more realistic learning environment. Therefore, to overcome these challenges, more focused studies on virtual technologies and extensive digital studies on design learning should be conducted with more number of participants.

As Oxman said (2008) digital methodologies in design education enhance performative process in design solving. It could be the reason of why participants found VR more intentional to use when compared to paper-based tools. In addition to Oxman’s (2008) concerms, Rieuf et al., (2017) also supports the idea that immersive design tools provide pleasurable and good vectoral for the designers for the intentional use. They also found in their experiment that VR is simple, manageable (easy to use), motivating (useful), agreeable and pleasant (enjoyment). The experimental study of this thesis supports the outcomes of these previous studies with reference of statistical results. Similar to Ding, Liew, Maher, Gero et al., (2003), which found that 3D virtual worlds are more effective when compared with traditional approaches, this thesis also found that VR is more effective than paper-based environment. Also, Rahimian and Ibrahim (2011) found that 3D sketching is more effective when compared with pen and paper sketching.

Balog and Pribeanu (2009) stated that perceived ease of use has a positive effect on intention to use. They supported that if users feel free and effortless while using a system, they will have positive intention to use this system. However, in this thesis, it was found that there is not any significant relationship between perceived ease of use and intention to use, but there is a significant relationship between perceived usefulness and intention to use, which is also supported by Davis et al. (1989). In addition to statements above, according to Rieuf et al.'s (2017) study, industrial design students found VR more simple, practical, manageable, inviting, appealing and motivating when it is compared with traditional methods to create mood boards. In this thesis, basic design students also found VR intentional to use, enjoyable, pleasant, easy to use and useful during the basic design problem solving activity when it is also compared with paper-based environment.

When the results within each group are analyzed in terms of TAM, there are no significant differences in terms of four aspects of TAM regarding the responses of VR and paper- based participants. However, when the results between the groups are analyzed, there are no significant differences in terms of perceived usefulness and perceived ease of use, but intention to use and the perceived enjoyment differed statistically in VR and paper based groups. It means that participants found VR more enjoyable.

With reference to the literature review, the results of this experimental study also support the studies (Davis et al., 1989; Venkantesh, 2000) which stated that there is a correlation between perceived usefulness and intention to use. However, although certain studies (Venkantesh, 2000; Balog & Pribeanu, 2009) stated that there is a correlation between perceived ease of use and perceived enjoyment, this study does not support this statement., but this study found a correlation between perceived Usefulness and perceived enjoyment as a contrubition to both TAM and use of VR literature.

CHAPTER VI

CONCLUSION

This study was an attempt to analyze and assess the usability of VR in basic design problem solving process. Efficiency, effectiveness and satisfaction as usability metrics were analyzed. In order to assess usability, ISO standards were taken as a base. The contribution of this study to the scientific literature is two-fold: One is the adaptation of the technology acceptance studies as TAM into the basic design context, and second is the comparison of VR with paper-based tools in terms of four components of TAM. Different than previous studies, which compared computer aided method with traditional methods, this study is significant in terms of showing differences of VR and paper tools on perceived enjoyment and intention to use. These two aspects are playing key role when reviewing the design literature and effecting also student performance in design learning and engagement.

Twenty participants involved in this experimental study voluntarily and they were seperated into two groups which are VR and paper-based groups. TAM, effectiveness, PT and TFT were analyized within and between groups. TAM questionnaires found reliable according to Cronbach' alpha values. Furthermore, participants found VR immersive and they involve in VR which is demonstrated by PT. The result of the TFT shows that a few of participants familiar with VR. However most of them very familiar with computer technology.

Thereby, TAM was used as a satisfaction measurement tool. The analysis of effectiveness and TAM enabled the usability of VR in basic design an insight on the problem solving in both traditional and VR methods. Moreover, effectiveness was calculated with the measures of archived goals and its completeness and accuracy as defined by ISO in 1998. According to results of the effectiveness test, VR group is the more effective in VR than paper-group, and it is also the most effective environment between groups.

According to the correlation and regression results, perceived usefulness and intention to use, and also perceived enjoyment and perceived usefulness items are correlated which is new contribution for the literature. In addition to that, there are also statistically significant regression results between perceived usefulness and intention to use. Therefore, it can be said that, given answers to intention to use items predict perceived usefulness items.

For limitations it is stated that, in this experimental study, minimum system requirements were used for Oculus Rift DK2, thus, sometimes system was failed during the experiment. Some of the participants started their design again and it may cause the learning effect. Because of the lack of system to calculate efficiency test of ISO, it was ignored in the experiment part. Experiment setting is not very suitable for the research for instance, FF212 computer lab is a free lab that other students can use during the experiment, and it is not available during the other courses given in this lab. Therefore, it was hard to find that lab quiet and empty. Furthermore, it is closed after 5:40 pm, some of the participants were available to attend the experiment after 5:40 pm, which is the end of their schedule, therefore some male participants could not attend the experiment. Because of that, genders were not divided into equally for both groups. It was also difficult to find a source to support the research question. It is found two studies which is adequately related with the concepts of usability and design. This experimental study will be the pioneer to mixed concepts, which are usability and basic design, of VR.

For further studies, external variables as gender differences can be searched between environments to understand the approaches of male and female to VR technologies. Because of this study has design concepts, for further studies usability of VR can be analized to compare creativity between environments. In addition, efficiency test should be studied to understand usability deeply. If it was also researched, there would be different results to affect the experimental study. In order to understand how digital technologies support problem solving activity, different methods can also be used, for instance AR, VR and CAD comparisons.

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APPENDICES

A. DESIGN PROBLEM BRIEFS

APPENDIX A1

VIRTUAL REALTY DESIGN PROBLEM 1

İHSAN DOĞRAMACI BİLKENT UNİVERSİTY	FA 101 BASIC DESIGN	VR-based problem 1

- **Qualities of design:**
  - Unity
  - Order
  - Harmony
  - Hierarchy
  - Balance
  - Rhythm
- ***Characteristics of design elements:***
  - Shape
  - Size/Scale/Proportion
  - Direction/Orientation

Systems of organization:

- Central
- Axial
- Radial
- Linear
- Gridal
- Nodal/Multi-centered
- Clustered

Use Oculus Rift head set touch set

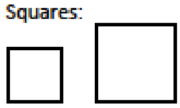
Google Blocks application

3D MODEL OF FLOW OF SPACE

You have already worked on the notions of "variation" and "transformation" with the ultimate aim to understand how they can help you to enrich your designs.

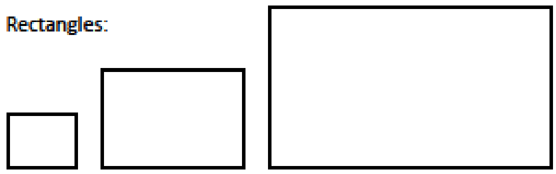
Now, you should develop a 3-D ***virtual*** concept model that represents a flow of space within a design field. This flow is composed of (minimum 6 and maximum 12) squares and (minimum 3 and maximum 6) rectangles (minimum 3 and maximum 6) where the different proportions should be used for both rectangles and squares (2 different squares, 3 different rectangles). You could also use linear elements with same proportion of geometric shape to elaborate the relations.
It is assumed that your 3D model is in the space so that the flow should be understandable from every side of your model.

Squares:



1 unit 2 unit

Rectangles:



1 unit 2 unit 3 unit

Evaluation criteria for the assessment of your 3D model will be as

follows:

- achievement of *qualities of design*
- quality of the verbal / visual presentations
- consistency among ***characteristics of design elements***
- achievement of qualities of ***systems of organization***

APPENDIX A2

PAPER BASED DESIGN PROBLEM 1

<table>
<tr><td>İHSAN DOĞRAMACI BİLKENT UNİVERSİTY</td><td>FA 101
BASIC DESIGN</td><td>Paper-based problem 1</td></tr>
<tr><td>

• **Qualities of design:**
- **Unity**
- **Order**
- **Harmony**
- **Hierarchy**
- **Balance**
- **Rhythm**

• ***Characteristics of design elements:***
- **Shape**
- **Size/Scale/Proportion**
- **Direction/Orientation**

Systems of organization:
- **Central**
- **Axial**
- **Radial**
- **Linear**
- **Gridal**
- **Nodal/Multi-centered**
- **Clustered**

</td><td colspan="2">

3D MODEL OF FLOW of SPACE

You have already worked on the notions of "variation" and "transformation" with the ultimate aim to understand how they can help you to enrich your designs.

Now, you should develop a 3-D concept model that represents a flow of space within a 20x20x20 centimeters design field. This flow is composed of (minimum 6 and maximum 12) squares and rectangles (minimum 3 and maximum 6 for each shape) where the lengths can be only 4, 8 or 16 centimeters (4x4 square, 4x8 rectangle, 8x8 square, 8x16 rectangle). You could also use linear elements with same dimensions to elaborate the relations.

It is assumed that your 3D model is in the space so that the flow should be understandable from every side of your model.

Evaluation criteria for the assessment of your 3D model will be as

follows:

- achievement of *qualities of design*
- quality of the verbal / visual presentations
- consistency among *characteristics of design elements*
- achievement of qualities of *systems of organization*

</td></tr>
<tr><td>Use your model making and drawing equipment.</td><td colspan="2"></td></tr>
</table>

APPENDIX A3

VR BASED DESIGN PROBLEM 2

İHSAN DOĞRAMACI BİLKENT UNİVERSİTY

FA 101

BASIC DESIGN

VR-based problem 2

- **Qualities of design:**
  - Unity
  - Order
  - Harmony
  - Hierarchy
  - Balance
  - Rhythm
- ***Characteristics of design elements:***
  - Shape
  - Size/Scale/Proportion
  - Direction/Orientation

Systems of organization:

- Central
- Axial
- Radial
- Linear
- Gridal
- Nodal/Multi-centered
- Clustered

Use Oculus Rift head set touch set

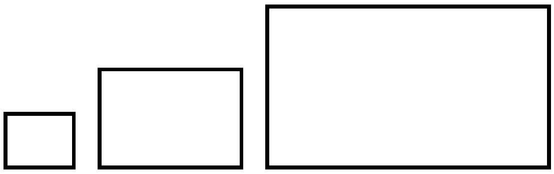
Google Blocks application

3D MODEL OF FLOW OF SPACE

You have already worked on the notions of "variation" and "transformation" with the ultimate aim to understand how they can help you to enrich your designs.

Now, you should develop a 3-D ***virtual*** concept model that represents a flow of space within a design field. This flow is composed of (minimum 6 and maximum 12) rectangles where the different proportions should be used for both rectangles (3 different rectangles).
You could also use linear elements with same proportion of geometric shape to elaborate the relations.
It is assumed that your 3D model is in the space so that the flow should be understandable from every side of your model.

Rectangles:



1 unit 2 unit 3 unit

Evaluation criteria for the assessment of your 3D model will be as follows:

- achievement of *qualities of design*
- quality of the verbal / visual presentations
- consistency among *characteristics of design elements*
- achievement of qualities of *systems of organization*

APPENDIX A4

PAPER BASED DESIGN PROBLEM 2

İHSAN DOĞRAMACI BİLKENT UNİVERSİTY	FA 101 BASIC DESIGN	Paper-based problem 2

• Qualities of design:

- Unity
- Order
- Harmony
- Hierarchy
- Balance
- Rhythm

• Characteristics of design elements:

- Shape
- Size/Scale/Proportion
- Direction/Orientation

Systems of organization:

- Central
- Axial
- Radial
- Linear
- Gridal
- Nodal/Multi-centered
- Clustered

Use your model making and drawing equipment.

3D MODEL OF FLOW of SPACE

You have already worked on the notions of "variation" and "transformation" with the ultimate aim to understand how they can help you to enrich your designs.

Now, you should develop a 3-D concept model that represents a flow of space within a 20x20x20 centimeters design field. This flow is composed of (minimum 6 and maximum 12) squares (minimum 3 and maximum 6) where the lengths can be only 4, 8 or 16 centimeters (4x4 square, 8x8 square, 16x16 rectangle). You could also use linear elements with same dimensions to elaborate the relations.

It is assumed that your 3D model is in the space so that the flow should be understandable from every side of your model.

Evaluation criteria for the assessment of your 3D model will be as

follows:

- achievement of *qualities of design*
- quality of the verbal / visual presentations
- consistency among *characteristics of design elements*
- achievement of qualities of *systems of organization*

B. QUESTIONNAIRES

APPENDIX B1

PRESENCE TEST QUESTIONNAIRE

Presence Test adapted from B. Witmer and M., Singer, 1998. Measuring Presence in Virtual Environments: A Presence Questionnaire. *Presence: Teleoperators and Virtual Environments*, 7(3), 225-240.

	Presence Test					
	Please place an "X" in the appropriate box to rate the following items using scale of 1-5: compelling to not compelling	1	2	3	4	5
1	How much were you able to control events?					
2	How responsive was the environment to actions that you initiated (or performed)?					
3	How natural did your interactions with the environment seem?					
4	How completely were all of your senses engaged?					
5	How much did the visual aspects of the environment involve you?					
6	How much did the auditory aspects of the environment involve you?					
7	How natural was the mechanism which controlled movement through the environment?					
8	How aware were you of events occurring in the real world around you?					
9	How aware were you of your display and control devices?					
10	How compelling was your sense of objects moving through space?					
11	How inconsistent or disconnected was the information coming from your various senses?					
12	How much did your experiences in the virtual environment seem consistent with your real-world experiences?					
13	Were you able to anticipate what would happen next in response to the actions that you performed?					
14	How completely were you able to actively survey or search the environment using vision?					
15	How well could you identify sounds?					
16	How well could you localize sounds?					
17	How well could you actively survey or search the virtual environment using touch?					
18	How compelling was your sense of moving around inside the virtual environment?					
19	How closely were you able to examine objects?					
20	How well could you examine objects from multiple viewpoints?					
21	How well could you move or manipulate objects in the virtual environment?					
22	To what degree did you feel confused or disoriented at the beginning of breaks or at the end of the experimental session?					
23	How involved were you in the virtual environment experience?					
24	How distracting was the control mechanism?					
25	How much delay did you experience between your actions and expected outcomes?					
26	How quickly did you adjust to the virtual environment experience?					
27	How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?					
28	How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?					
29	How much did the control devices interfere with the performance of assigned tasks or with other activities?					
30	How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?					
31	Did you learn new techniques that enabled you to improve your performance?					
32	Were you involved in the experimental task to the extent that you lost track of time?					

APPENDIX B2

TAM QUESTIONNAIRE

TAM questionnaire adapted from Chesney, 2006; Davis, 1989; 1993; Davis, et. al, 1989; Hsu & Lu, 2004; Van Raaij & Schepers, 2008; Venkatesh, 2000; Venkatesh, Morris, Davis & Davis, 2003.

Name:

Age:

Gender:

Class:

Eye Disorder (lens or glasses):

Cybersickness:

Claustrophobia:

Technology Acceptance Model Questionnaire for Paper-Based Environment

Please place an "X" in the appropriate box to rate the following items using scale of 1-5:

1= strongly disagree 2=disagree 3=neutral 4=agree 5=strongly agree

	Perceived Usefulness	**1**	**2**	**3**	**4**	**5**
1	Paper-based tools enables me to accomplish task more quickly					
2	Paper-based tools has improved my quality of work					
3	Paper-based tools makes it easier to do my job					
4	Paper-based tools have improved my productivity					
5	Paper-based tools gives me greater control over my job					
6	Paper-based tools enhance my effectiveness on the job					
	Perceived Ease of Use					
7	My interaction with the paper-based tools has been clear and understandable					
8	Overall, the paper-based tools are easy to use					
9	Learning to operate the paper-based tools were easy for me					
10	I rarely become confused when I use the paper-based tools					
11	I rarely make errors when using the paper-based tools					
12	I am rarely frustrated when using the paper-based tools					
	Intention to Use					
13	I intend to use any system using paper-based environment when it becomes available in basic design					
14	Assuming I had access to the paper-based environment, I intend to use it					
15	I predict that I would use paper-based environment frequently					
	Perceived Enjoyment					
16	System is fun to use					
17	System is pleasant					
18	Feel enjoyment					
19	I would like to repeat same experience					
20	It was interesting experience					

APPENDIX B3

TAM QUESTIONNAIRE

TAM questionnaire adapted from Chesney, 2006; Davis, 1989; 1993; Davis, et. al, 1989; Hsu & Lu, 2004; Van Raaij & Schepers, 2008; Venkatesh, 2000; Venkatesh, Morris, Davis & Davis, 2003.

Name, Surname:

Age:

Gender:

Class:

Eye Disorder (lens or glasses):

Cybersickness:

Claustrophobia:

Technology Acceptance Model Questionnaire for VR

Please place an "X" in the appropriate box to rate the following items using scale of 1-5:

1= strongly disagree 2=disagree 3=neutral 4=agree 5=strongly agree

	Perceived Usefulness	**1**	**2**	**3**	**4**	**5**
1	Virtual reality enables me to accomplish task more quickly					
2	Virtual reality has improved my quality of work					
3	Virtual reality makes it easier to do my job					
4	Virtual reality has improved my productivity					
5	Virtual reality gives me greater control over my job					
6	Virtual reality enhances my effectiveness on the job					
	Perceived Ease of Use					
7	My interaction with the virtual reality has been clear and understandable					
8	Overall, the virtual reality is easy to use					
9	Learning to operate the virtual reality was easy for me					
10	I rarely become confused when I use the virtual reality					
11	I rarely make errors when using the virtual reality					
12	I am rarely frustrated when using the virtual reality					
	Intention to Use					
13	I intend to use any system using virtual reality when it becomes available in basic design courses					
14	Assuming I had access to the virtual reality system, I intend to use it					
15	I predict that I would use virtual reality frequently					
	Perceived Enjoyment					
16	System is fun to use					
17	System is pleasant					
18	Feel enjoyment					
19	I would like to repeat same experience					
20	It was interesting experience					

APPENDIX B4

TECHNOLOGY FAMILIARITY TEST

Technology Familiarity Test

1. **Have you ever used a computer (i.e., desktop, notebook, or iPad)?**
   a. Yes. Which? Desktop Notebook Tablet
   b. No
2. **How often do you use the computer each week?**
   a. Less than 1 hour/week
   b. Between 1-5 hours/week
   c. More than 5, but less than 10 hours/week
   d. 10 or more hours/week
3. **How long have you been using the computer?**
   a. Less than 6 months
   b. Between 6 months and 1 year
   c. More than 1 year, but less than 5 years
   d. 5 or more years
4. **Have you ever used the Internet?**
   a. Yes
   b. No
5. **How often do you use the Internet each week?**
   a. Less than 1 hour/week
   b. Between 1-5 hours/week
   c. More than 5, but less than 10 hours/week
   d. 10 or more hours/week
6. **How long have you been using the Internet?**

a. Less than 6 months

b. Between 6 months and 1 year

c. More than 1 year, but less than 5 years

d. 5 or more years

7. Have you ever used virtual reality system?

a. Yes. Which?

b. Google cardboard VR glass with mobile phone Oculus Rift HTC Vive

c. No

8. How often do you use VR each week?

a. Less than 1 hour/week

b. Between 1-5 hours/week

c. More than 5, but less than 10 hours/week

d. 10 or more hours/week

9. How long have you been using the VR?

a. Less than 6 months

b. Between 6 months and 1 year

c. More than 1 year, but less than 5 years

d. 5 or more year

APPENDIX B4

TECHNOLOGY FAMILIARITY TEST

Effectiveness Test is proposed by author,2018.

Effectiveness Test Evaluation Forms

Please give a score from 1 to 10 for each aspect.
Example: 3 points for quality of design, 4 points for characteristics of design element, etc.

Participant:

Project:

Design aspects;
-Quality of Design: *Please give a score out of 10. While giving score, please take into consideration above.*

- Unity
- Order
- Harmony
- Hierarchy
- Balance
- Rhythm

SCORE:
-Characteristics of Design Element: *Please give a score out of 10. While giving score, please take into consideration above.*

- Shape
- Size/Scale/Proportion
- Direction/Orientation

SCORE:
-System of Organization: *Please give a score out of 10. While giving score, please take into consideration above.*

- Central
- Axial
- Radial
- Linear
- Gridal
- Nodal/Multi-Centered

SCORE:

TOTAL SCORE:

APPENDIX C

ETHICAL APPROVALS

Bilkent Üniversitesi

Akademik İşler Rektör Yardımcılığı

Tarih: 18 Ocak 2018

Gönderilen: Yrd.Doç.Dr. Yasemin Afacan, Dilay Seda Özgen

Gönderen: Doç. Dr. Fatma Taşkın
İnsan Araştırmaları Etik Kurulu Başkanı

Konu: *"Usability of ... "* çalışması etik kurul onayı

Üniversitemiz İnsan Araştırmaları Etik Kurulu, 18 Ocak 2018 tarihli görüşme sonucu, *"Usability of Virtual Reality in Basic Design Course"* isimli çalışmanız kapsamında yapmayı önerdiğiniz etkinlik için etik onay vermiş bulunmaktadır. Onay, ekte verilmiş olan çalışma önerisi, çalışma yürütücüleri, ve bilgilendirme formu için geçerlidir.

Bu onay, yapmayı önerdiğiniz çalışmanın genel bilim etiği açısından bir değerlendirmesine karşı gelmektedir. Çalışmanızda, kurulumuzun değerlendirmesi dışında kalabilen özel etik ve yasal sınırlamalara uymakla ayrıca yükümlüsünüz.

Etik Kurul Üyeleri:

Ünvan / İsim	**Bölüm / Uzmanlık**	**İmza**
1. Doç.Dr. Fatma Taşkın	İktisat	
2. Prof.Dr. Erdal Onar	Hukuk	
3. Prof.Dr. Haldun Özaktaş	Elektrik ve Elektronik Müh.	-izinli-
4. Doç.Dr. Işık Yuluğ	Moleküler Biyoloji ve Genetik	
5. Yrd.Doç.Dr. Gül Günaydın	Psikoloji	
Yd.1.Doç.Dr. Çiğdem Gündüz Demir	Bilgisayar Mühendisliği	
Yd.2. Yrd.Doç.Dr. A.Barış Özbilen	Hukuk	-Yedek Üye-

Kurul karar/toplantı No: 2018_01_18_03

Bilkent Üniversitesi, 06800 Bilkent, Ankara • Telefon: (312) 290 12 13 • (312) 290 12 14 • Faks: (312) 266 41 52

(Form Student_EN*)

Ethics form for graduate and undergraduate students - human participants

Note - group projects fill in one copy with all your names on it. Consult your project supervisor for advice before filling in the form.

Your name(s): Dilay Seda Özgen Project Supervisor: Assist. Prof. Yasemin Afacan

A. Write your name(s) and that of your supervisor above.
B. Read section 2 that your supervisor will have to sign. Make sure that you cover all these issues in section 1. Discuss what you are going to put on the form with your project supervisor.
C. Sign the form and get your project supervisor to complete section 2 and sign the form.

1. Project Outline (to be completed by student(s))

(i) Full Title of Project:

Usability of Virtual Reality in Basic Design Course

(ii) Aims of project:

The aim of the study is understanding the usability of VR in basic design education in terms of effectiveness and technology acceptance model (TAM).

(iii) What will the participants have to do? (brief outline of procedure; please draw attention to any manipulation that could possibly be judged as deception; *for survey work, a copy of the survey should be attached to this form*):

There are three phases of the experiment. It is expected from participants to work with paper-based instruments (cardboards, papers, glue, etc.) to create their design project, also with virtual reality environment provided by the head mounted system (head set, movement sensors, touch controls). Participants will create their projects in both environments. After that, they will fill the specific questionnaires, which are TAM questionnaire for paper-based environment, TAM questionnaire for VR environment, presence test and technology familiarty test. All questionnaires were adapted from the literature and they were modified according to study.

(iv) What sort of people will the participants be and how will they be recruited? In the case of children state age range. (*Any participant who has not lived through his/her 18th birthday is considered to be a child!*)

All the participants are above 18 years old and they are selected on voluntary basis from the 1st year undergraduate students in Bilkent University, who are taking FA101-102 Basic Design courses.

*If you are testing children or other vulnerable individuals, state whether all applicants have CRB** clearance*

(v) What sort stimuli or materials will your participants be exposed to? Tick the appropriate boxes and then explain the form that they take in the space below, please draw attention to any content that could conceivably upset your participants).
Questionnaires[x]; Pictures[ ]; Sounds [x]; Words[x]; Caffeine[ ]; Alcohol[ ]; Other[ ].

* Adapted from *www.york.ac.uk/depts/psych/www/research/ethics/HumanProjForm.doc*
** Criminal Records Bureau – Please attach relevant clearance documentation.

DSÖ. YA.

(vi) Consent Informed consent must be obtained for all participants before they take part in your project. The form should clearly state what they will be doing, drawing attention to anything they could conceivably object to subsequently. It should be in language that the person signing it will understand. It should also state that they can withdraw from the study at any time and the measures you are taking to ensure the confidentiality of data. If children are recruited from schools you will require the permission of the head teacher, and of parents. Children over 14 years should also sign an individual consent form themselves. When testing children you will also need Criminal Records Bureau clearance. Testing to be carried out in any institution (prison, hospital, etc.) will require permission from the appropriate authority. (Please include documentation for such permission.)

Who will you seek permission from?

Participants and instructors of them. They are all older than 18 years old.

Please attach the consent form you will use. Write the "brief description of study" in the words that you will use to inform the participants here.

(vii) **Debriefing - how and when will participants be informed about the experiment, and what information you intend to provide? If there is any chance that a participant will be 'upset' by taking part in the experiment what measures will you take to mitigate this?**

It is asked to participants who have cybersickness (stomach upset, and dizziness caused by technology) and claustrophobia cannot attend this experiment. If they don't know they have these or not, they will try the VR set, and if then they feel bad, they will not conduct the experiment.

(viii) **What procedures will you follow in order to guarantee the confidentiality of participants' data?**

Each participant, who takes part in the structured interview process, will be asked to sign a consent form to satisfy ethical procedures (See attached consent form).

In the information consent form there is a statement which is signed by the graduate student and the supervisor that "we confirm that the confidentiality and anonymity will be maintained and the participant will not be identified from any publications".

(vii) **Give brief details of other special issues the ethics committee should be aware of.**

(viii) **Tick any of the following that apply to your project**

[x] it uses Bilkent facilities;
[ ] it uses stimuli designed to be emotive or aversive;
[ ] it requires participants to ingest substances (e.g., alcohol);
[ ] it require participants to give information of a personal nature;
[ ] it involves children or other vulnerable individuals;
[ ] it could put you or someone else at risk of injury.

Student's signature: ...Dilay Seda Özgen...date: ..11.01.2018...................
(all students must sign if this is a group project, please initial all other pages)

The signatures here signify that researchers will conform to the accepted ethical principles endorsed by relevant professional bodies, in particular to

Declaration of Helsinki (WMA):
http://www.wma.net/en/30publications/10policies/b3/index.html

Ethical Principles of Psychologists and Code of Conduct (APA):
http://www.apa.org/ethics/code2002.html

Ethical Standards for Research with Children (SCRD):
http://www.srcd.org/about-us/ethical-standards-research

2. Supervisor's assessment (supervisor to complete - circle yes or no)

Yes/No - I confirm that I have secured the resources required by this project, including any workshop time, equipment, or space that are additional to those already allocated to me.

Yes/No - The design of this study ensures that the dignity, welfare and safety of the participants will be ensured and that if children or other vulnerable individuals are involved they will be afforded the necessary protection.

Yes/No - All statutory, legislative and other formal requirements of the research have been addressed (e.g., permissions, police checks)

Yes/No - I am confident that the participants will be provided with all necessary information before the study, in the consent form, and after the study in debriefing.

Yes/No - I am confident the participant's confidentiality will be preserved.

Yes/No - I confirm that students involved have sufficient professional competency for this project.

Yes/No - I consider that the risks involved to the student, the participants and any third party are insignificant and carry no special supervisory considerations. If you circle "no" please attach an explanatory note.

No/Yes - I would like the ethics committee to give this proposal particular attention. (Please state why below)

Supervisor's signature: .... date: 18.01.2018

<u>Please e-mail an electronic version of this word processed form (without signatures) along with other application material to the committee to start the evaluation process.</u> Paper copies of all application material, (properly signed where indicated, and initialed on all other pages) should be sent after possible modifications suggested by the committee are finalized.

Bilkent University does not allow the use of students of research investigators as participants. Students who have the potential of being graded by the investigators during or following the semester(s) in which the study is being carried out should not participate in the study. Students may not receive any credit for any university course, with the exception of the GE250/GE251 courses, for their participation. The GE250 and GE251 (Collegiate Activities I and II) courses include an optional activity which encompasses volunteering as a participant in a research project.

(Form Staff_EN*)

Staff Application Form for Experiments with Human Participants

(A separate application form must be completed for each experiment and staff member.)

Please check one: ___ ***I need a formal approval letter for an external agency (TÜBİTAK, etc.)***

__X_ ***An internal communication letter informing me of the approval will be sufficient***

1. Name of applicant (graduate students should indicate their supervisors)

Assist. Prof. Dr. Yasemin Afacan

2. Funder of grant/studentship if any:

3. Full title of experiment/project

Usability of Virtual Reality in Basic Design Course

4. When do you wish to start data collection: __15.02.2018______________

5. Aims of project:

The aim of the study is understanding the usability of VR in basic design in terms of effectiveness and technology acceptance model (TAM).

6. What will the participants have to do? (Provide a brief outline of procedure, *for survey work, a copy of the survey should be attached to this form.*) Please indicate if the participants may be exposed to stimuli which may upset them:

There are three phases of the experiment. It is expected from participants to work with paper-based instruments (cardboards, papers, glue, etc.) for creating their design project, also with virtual reality environment provided by head mounted system (head set, movement sensors, touch controls). Participants will create their projects in both environments. After that, they will fill the following questionnaires: Technology Acceptance Model (TAM) questionnaire for paper-based environment; TAM questionnaire for VR environment; presence test and technology familiarity test. All questionnaires were adapted from the related literature and they were modified according to the study.

7. What sort of people will the participants be and how will they be recruited? In the case of children state age range. (*Any participant who has not lived through his/her 18th birthday is considered to be a child!*)

All the participants are above 18 years old and they are selected on voluntary basis from the 1st year undergraduate students in Bilkent University, who are taking FA101-102 Basic Design courses.

8. Arrangements for consent and debriefing (attach information sheet and consent form)

Each participant, who takes part in the structured interview process, will be asked to sign a consent form to satisfy ethical procedures (See attached consent form). Before conducting surveys, a brief explanation will be also given as to how data from their responses will be used.

It is asked to participants who have cybersickness (stomach upset, and dizziness caused by technology) and claustrophobia cannot attend this experiment. If they don't know they have these or not, they will try the VR set, and if then they feel bad, they will not conduct the experiment.

9. How will you guarantee confidentiality of participants?

In the information consent form there is a statement, which is signed by the graduate student and her supervisor that "we confirm that the confidentiality and anonymity will be maintained and the participant will not be identified from any publications".

* Adapted from *www.york.ac.uk/depts/psych/www/research/ethics/StaffPGEthicsForm.doc*

10. Please e-mail an electronic version of this word processed form (without signatures) along with other application material to the committee to start the evaluation process. Paper copies of all application material, (properly signed where indicated, and initialed on all other pages) should be sent after possible modifications suggested by the committee are finalized.

Signature(s):

Person carrying out the work

.......Graduate student: Dilay Seda Özgen..

Supervisor, grant holder, or Principal Investigator: I am satisfied that that the procedures adopted will ensure the dignity, welfare and safety of all participants in this work.

........Assist. Prof. Yasemin Afacan...

The signature above signifies that researchers will conform to the accepted ethical principles endorsed by relevant professional bodies, in particular to

Declaration of Helsinki (WMA):
http://www.wma.net/en/30publications/10policies/b3/index.html

Ethical Principles of Psychologists and Code of Conduct (APA):
http://www.apa.org/ethics/code2002.html

Ethical Standards for Research with Children (SCRD):
http://www.srcd.org/about-us/ethical-standards-research

Bilkent University does not allow the use of students of research investigators as participants. Students who have the potential of being graded by the investigators during or following the semester(s) in which the study is being carried out should not participate in the study. Students may not receive any credit for any university course, with the exception of the GE250/GE251 courses, for their participation. The GE250 and GE251 (Collegiate Activities I and II) courses include an optional activity which encompasses volunteering as a participant in a research project.

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