ANALYZING THE DESIGN BEHAVIOUR OF SKETCHING PROCESS WHILE BEING INSIDE VIRTUAL ENVIRONMENT

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Abstract

Architectural representation of early design phases contains sketching such as diagrams, analyze maps, and freehand drawings [2D and 3D]. Sketching is a critical representational method and the sketch tools are evolving with the technology. New mediums and tools have built with computer technology. Firstly computer-aided design tools [CAD] have emerged, so the designer can sketch through a computer display. Then, Virtual Reality [VR] environment have given the chance of walking around the virtual environment with 360 degrees, interacting and experiencing with the sketch while drawing. This study is based on the idea creation with the sketch method during the architectural design process with the manual [paper and pencil] and VR [Google Blocks] tools. Google Blocks is software by Google to draw and model inside VR. The study will be conducted with novice designers at a first-year basic design studio as a first project separated as paper-based sketchers and Google Blocks sketchers. Common specialties of these student groups are that they have the same background for manual and VR sketching tools which is their first meeting with the sketching as a design method. Each group will use the different sketching tool during the design process. These two groups are briefed with the same project that designing a module which can be 2D or 3D shape, then they will build a pavilion with their module. This study employs protocol analysis for comparing these two groups cognitive design protocols in both manual and 3D sketching phases. The research will analyze the design behaviours and create an understanding of relation the designers' cognitive abilities to 'problem-space' and 'solution-space' quality based on the sketch tool. Suwa, Purcell and Gero's protocol analysis coding scheme will be used for creating segments of the design processes of the students. The study samples the variables of Pour Rahmian et. al defined the dependent variables as 'solution quality', 'certainty of the correctness of the solution', 'total solution time and experienced difficulty in design problem solving' (Pour Rahimian F. a., 2011) and the independent variables were fully manual, and fully VR sketching modes. The design quality is defined as derivability from module to pavilion. The study hypotheses that the VR sketchers have tendency to design 3D module more than 2D sketchers.

Keywords: Manual Sketching, VR Sketching, Protocol Analysis, Design Studio, Design Thinking.

1.   Introduction

Designers draw for communication, storytelling and idea representation. They use sketches, technical drawings, mock-ups, elevations, perspectives, 3D computer models and presentation models, in order to fulfill the need of communication with others during the design process (Dorta T. , 2006). Bilda and Demirkan cited that sketching is an essential phase of design process which includes solutions to reveal possibilities and conflicts and also it gives the chance to improve and clarify design ideas, develop conceptual ideas and aid the problem solving (Bilda & Demirkan, 2002). Arnheim explained that thoughts need forms and the forms must be derived from a medium (Arnheim, 2015). According to these explanations, sketching is one of the important phases of design process for communication with designer's own thoughts and representation to the others and also developing the ideas with its potentials and weaknesses. Sketching with a variety of tools is one of the essential phases of the design process. It is a design method which has a variety of tools such as paper, pen, computer-aided design, virtual environments, physical modeling (Fig. 01). It is one of the significant activity for design cognition studies to understand the designer's early design phases.
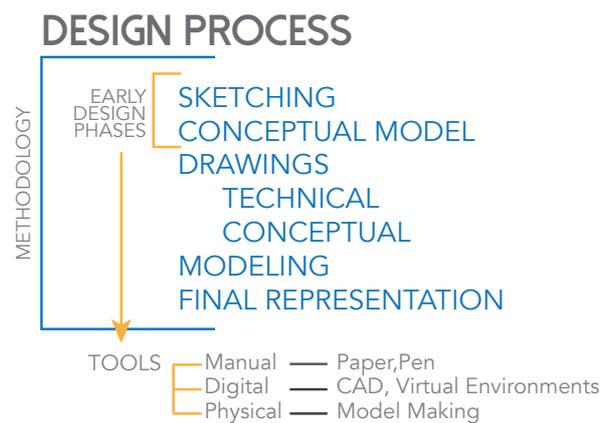

Figure 1. Design Process with Tool

This study supports the idea of the sketching is crucial for the design process, then the tools must be analyzed to reveal their contribution while developing the design ideas. Goel defines the sketching as enabler for the creative shift to reach new alternatives with lateral transformation in the solution space (Goel, 1992). His definition shows that embodying and flanking the ideas of the solution space creates the possibility to reach the creative solutions.

The design studio is where the designer learns the design thinking with the methodologies and the tools. Sketching activity is included in these methodologies and its tools have significance to teach the methodology. Manual sketching will be accomplished with paper and pencil. For VR sketching, HTC Vive Head Mounted Display will be used. Dorta explained that there are two different VR environments which are immersive and non-immersive (Dorta

T. , 2004), but in this study room-scale [HTC Vive Head Mounted Display] will be used as a sketching medium. Therefore the user can be immersed and allowed to walk around the 3D environment. Manual sketching and VR sketching has different potentials which can be both positive or negative. They can be triggered by different stimulants and visual imagery. The aim is to understand the effectiveness and creativity with both tools.

Designers have the role of reflecting their society. As Lawson explained that the role of designer in post-industrial society creates the necessity of post-industrial design process (Lawson, 2005). Virtual environments are the technology that belongs to the post-industrial reality. They offers the opportunity to design inside the medium with some hardware and software supports. How designers' creates paper-based sketches and VR-based sketches will be researched. Understanding the design behavior inside virtual environments with cognitive methodologies and comparing it with the paper-based environments is the aim of this study, so 'a protocol analysis' method will be conducted to understand the behaviours of designer while using HTC Vive HMD which provides to record **what user sees** (eye gaze), **does** and how **he/she behaves** while using. The designers will watch and name their moves with arguments. During this process designers' strategies will also be revealed to see the correlation.

2. Basis of the Study

This study discusses that how manual [2D] and VR [3D] sketching supports the architectural design studio for first year students. The literature of design cognition on architectural studio based on manual and digital sketching is used to create the basis of the research, methodology and the experiment.

While Schön described design is constructing knowledge and sketching is reflection-in-action (Schön, 1983), Goldschmidt defined design as a plan for making of something new which can emerge from the visual imagery as a conceptual framework for investigation (Goldschmidt, 1991). This two definition explains that design activity includes the visual imagery during sketching. Simon defined design as problem solving which is an ill-structured problem (Simon, 1973), so design problems cannot be solved as the logical approach of well-defined problems. Simon and Eastman's approach of reframing the ill-defined problem to solve the problem includes the decomposing the process as protocols (Eastman, 1960). As an ill-defined problem, the design process needs to decompose and it creates its own methodology to solve the design problem. Every stages of design process needs to analyze with its special features, therefore sketching which is a reflection-in-action that emerges from the visual imagery is first step of the design process to research on.

Goldschmidt explained that sketching has a critical part in design reasoning through unique visual imagery. She defined 'study sketches' as made very fast and idiosyncratic for its maker are the architects' tendency during early design stages to reach the design goal. She defined the sketching action with 'seeing as' [which is reflective criticism] and 'seeing that' [which is the analogical reasoning] and she explained that designer's reinterpretation with the sketch can provoke the creativity (Goldschmidt, 1991). It can be interpreted that designer sketching activity is creative with reflective criticism and analogical reasoning, so the researches support that design education also needs to include the sketching as a matter. This approach shows student needs to achieve sketching as a reflection of external representation.

There are different protocol analysis methodologies, one is concurrent protocol which includes thinking aloud and verbalization of design moves and the other is retrospective protocol which means name the moves after design practice. Suwa and Tversky is conducted a study that uses retrospective protocol analysis with categorizing the information which has also subclasses, so they can encode the information in the verbal approaches (Suwa & Tversky, 1997). Suwa, Purcell and Gero cited Dorst and Dijkhuis (1995) that how they separate the protocol analysis method as the process-oriented approach and the content-oriented approach. They described that process-oriented approach targets problem solving elements such as problem-states, operators, plans, goals, strategies. When it comes to content-oriented approach, it aims to explain that how designers see, think and recall their memory during design thinking. They added that even the content-oriented approach answers the purpose of designer-sketch interaction on cognitive level, it cannot explain the actions therefore it creates difficulty the comparison of designers. They proposed a coding schema to analyze designers cognitive interaction with sketches to solve the insufficiencies (Suwa, Purcell, & Gero, 1998).

Coding scheme for each segment, the cognitive actions of design students are coded into four action categories. The coding scheme was based on a psychological model where the four categories of the coding scheme corresponded to the levels at which incoming information was thought to be processed in human cognition (Goel, 1995). Thus the present study employs an analysis procedure with a content-oriented coding scheme and a process-oriented method of segmentation.

One of the samples of VR-sketching is Achten & De Vries's research which creates a user interface for VR-based sketching. They define features for the software they created that simple user interface which means natural gestures and easy to learn, so easy creation, easy manipulation, easy navigation in VR medium is important for them (Achten & De Vries, 2000). Google Blocks has also same kind of features such as easily gesture controlling, easy to create shapes and easy to manipulate them. Google Blocks also provides the experiencing the sketches inside VR environment with the walking and turning around feature.

This immersive situation creates both advantages and disadvantages. Dorta cited Donath et al. that immersive virtual space gives the chance of sketching 3D which is the evolution of conventional 2D sketch, though he added that VR sketching creates new challenges which are 'sketching with arms and body usage' and all body movement is necessary to generate any sketch (Dorta T. , 2006). Also, other difficulties are controlling the proportions at the perspective view of the environment, accuracy in the 3D space and scaling problems, new media interface and configuration of the equipment (Dorta T. , 2006). Still, when the designer/ student gets used to using the VR sketching tool, it becomes an extension of the body and user can use it with through gestures. This study supports that when a student learned the VR sketching, it is possible for VR to become a reflex as using a pencil to sketch. Besides that VR-based sketch has the advantages such as experiencing the design with 1/1 scale without physically constructed and even during early design phases and also seeing all scaling with one gesture.

3.   Methodology of the Study

This study is based on the idea creation and with the sketch method during the architectural design process with the manual [paper and pencil] and VR [Google Blocks] tools. Google Blocks is software by Google to draw and model inside VR. Google Blocks software is using with the HTC Vive HMD, so it can be experiencing with 360-degree perspective and room-scale walking option. Room-scale is creating a virtual space to design inside. 3D features of VR and 2D features of manual sketching as external representations will be compared during the design process.

The study will be conducted with novice designers at a first-year basic design studio as a first project separated as paper-based sketchers and Google Blocks sketchers. Common specialties of these student groups are that they have the same background for manual and VR sketching tools which is their first meeting with the sketching as a design method. They spent the same amount of time with 2D sketching and 3D sketching. They took lectures on design thinking and sketching. Each group will use the different sketching tool during the design process for the same design brief. All the students are briefed with the same project that designing a module which can be 2D or 3D shape, then they will build a pavilion with their module. They need to sketch both module and pavilion they imagine. Because of the VR environment are not suitable enough for collaborative design, all students will design their modules and pavilions with just the tutor. Each student will be recorded during sketching both video and audio. They will explain their moves and actions thinking aloud. The movement and eye-gazes of VR-based sketchers also will be tracked.

THE GROUP	THE BRIEF	SKETCHING	PROTOCOL ANALYSIS	
PAPER-BASED SKETCHERS	DESIGN A MODULE and A PAVILION by multiplying the module	Video capture Audio Recording Thinking aloud	Suwa - Coding Scheme physical,perceptual, functional, conceptual	
VR-BASED SKETCHERS	DESIGN A MODULE and A PAVILION by multiplying the module	Video capture Audio Recording Thinking aloud Movement Tracking Eye Tracking	Suwa - Coding Scheme physical,perceptual, functional, conceptual	

Figure 2. The Experiment

The experiment employs protocol analysis for comparing these two groups cognitive design protocols in both 2D and 3D sketching phases. The research will analyze the design behaviours and create an understanding of relation the designers' cognitive abilities to 'problem-space' and 'solution-space' quality based on the sketch tool. Suwa, Purcell and Gero have developed a scheme to code cognitive actions of the designers from the recorded videos and audios during design protocols (Suwa, Purcell, & Gero, 1998). According to their scheme, the actions of the designers are classified as four levels of cognitive actions which are physical, perceptual, functional and conceptual (Fig. 02) (Suwa, Purcell, & Gero, 1998). They coded those action relations which belong to the different levels based on their dependencies, triggering and relations, thus it created the benefit of systematically defined designer actions according to and cognitive behaviors of the designers were represented with the primitive actions (Suwa, Purcell, & Gero, 1998). Their methodology provides the opportunity of systematic protocol analysis.
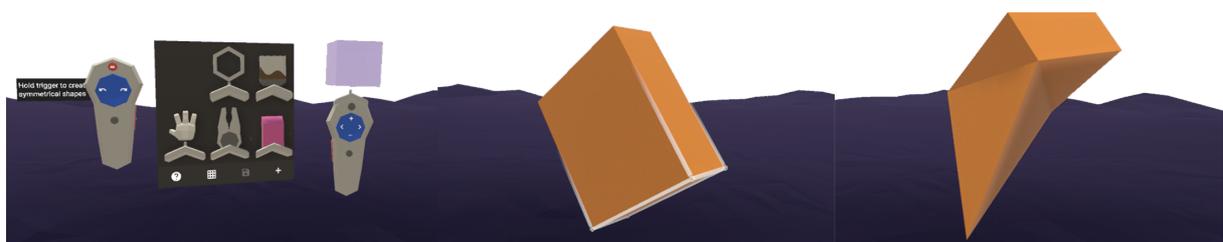

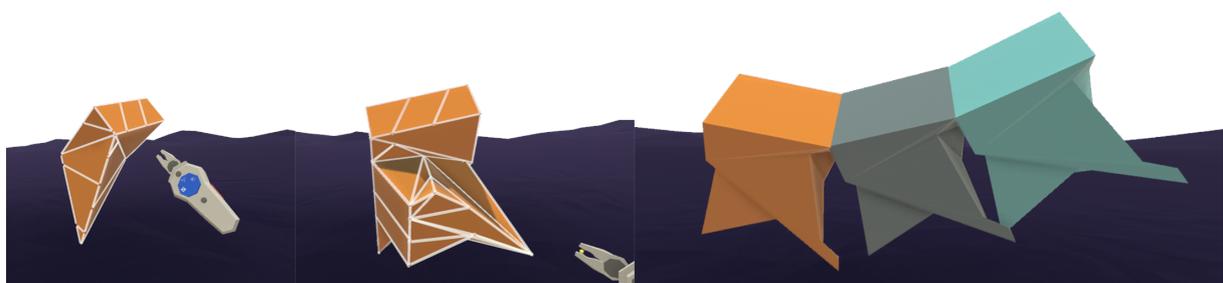Figure 3. Google Blocks Module Creation and Modification.

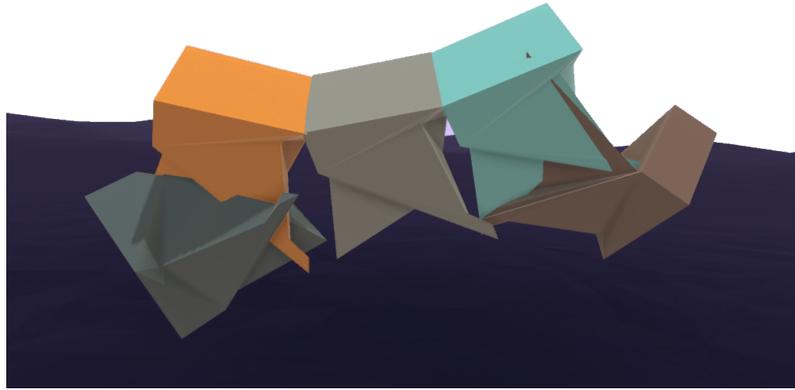Figure 4. Google Blocks Module Modification and Multiplication.

Figure 5. Google Blocks Module Multiplication.

The segments in this study employed steps that reflected the student's goal in terms of their design aim in this specific design problem of pavilion design (Fig.06). Every student's process has the different numbers of steps at the segmentation which depends on the variables as student's chosen path on problem solving, procedure of decision-making, learning effect, the tool (paper-VR) [Fig. 03, Fig. 04, Fig. 05]. The study is not claimed that the categories includes all the possibilities of the students' aims and activities during pavilion problem-solving process, though it can create a solution to decompose of the first students' design intention process for this design problem with defining the categories properly. The categories will be classified by analyzing the verbal protocols and watching the recordings of a number of times. Also the movement and eye-tracker data will be analyzed to support the category definitions. Categorized segments will include the Suwa, Purcell and Gero defined cognitive actions which are physical, perceptual, functional and conceptual (Suwa, Purcell, & Gero, 1998). This will explain the incoming information during thinking process in human cognition level. For this study, it is used the same action categories, though the encoded cognitive actions were revised for providing some insight into the comparison of sketching activity in paper-based vs VR-based.

The study samples the variables of Pour Rahmian et. al defined the dependent variables as 'solution quality', 'certainty of the correctness of the solution', 'total solution time and experienced difficulty in design problem solving' (Pour Rahimian F. a., 2011) and the independent variables were fully manual, and fully VR sketching modes. The design quality is defined as derivability from module to pavilion.

A. Define/Create a space component or an area
[which is the maximum dimensions of the pavilion]
    1. Trying the basic shapes with gestures.
      [Circle, Rectangle, Square, Lines]
    2. Trying the module jonits on the basic shapes.
      Trials of modules and joints simultaneously.
    3. Combination of 1 & 2.
    4. Looking around shapes 360-degrees. [VR]
    5. Defining the joint points on module trials.
    6. Combining 5-10 modules to see the behaviour of the shape.

B. Revisit the basic shapes to manipulation for complexity.
    1. Pushing and pulling on shapes to create complex shapes.
    2. Looking around shapes 360-degrees. [VR]
    3. Combination of 1 & 2.
    4. Defining the joint points on complex module trials.
    5. Looking around shapes 360-degrees. [VR]
    6. Combining 5-10 modules to see the behaviour of the shape.

C. Choosing some of the trials [both basic and complex] to develop
more.
    1. Manipulation with push and pulls.
    2. Redefinition of joint points.
    3. Redefinition of module to pavilion formation.
    4. Looking around shapes 360-degrees. [VR]

Figure 6. The Sample of Segmentation Categories [Basis on Fig3-4-5].

At all, this study will conducted to reach to understand the impacts of paper-based and VR-based sketching tools on design decisions on cognitive level of first year students at basic design studio. They will separate into two groups and design a module then a pavilion with multiplying the module in different environments. Each group will record on video with audio and VR-based sketching group will also tracked with movement tracker and eye-tracker. All collected data will analyzed based on the segmentation methodology of Suwa, Purcell and Gero's protocol analysis coding system. Also Pour Rahmian's variables will be implemented to this process. After the design process, students' modules and pavilions will be compared based on these methodologies. Tools' effect on design decisions and final product will be revealed on cognitive level.

3.1 Hypotheses

This study hypotheses that;
- While paper-based sketchers are reaching the design goals with the basic shapes, VR-based sketchers will create more complex shapes according the mediums capabilities. Their design moves, and arguments are developed around that.
- While Paper-based sketchers creates more alternative with basic shapes, VR-based sketchers will manipulate more than creating alternatives.

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