SOME PHENOMENA OF DESIGN THINKING IN THE CONCEPT GENERATION STAGE USING COMPUTER MEDIA

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Abstract. Today, the computer media has become more and more important in design process. It is not only used as kind of simulated and presented media. Also, various kinds of research start developing the computer aided design system and probing the possibility of using computers in creative activities. In recent years, many studies concentrate on the forepart of design, the concept generation stage, but most of them are based on conventional media such as papers and pencils. This study attempts to probe the different design thinking phenomenon produced through concept generation by computers and by conventional media; and the effects of the development and presence of design concept generation resulted from the merits and features of the computers themselves. The methodology used here is protocol analysis of gaining subject’s verbal data in think-aloud way and then encoding it to analyze. The outcome of this study is to find some phenomena of design thinking when using computers to progress concept generation, and suggest further studies relating to the topic of methodology.

1. Introduction

Since 1970, the scholars studying design activities have presented various models of the procedure. (Jones, 1970,1981; Archer, 1984; Pahl & Beitz, 1984; March, 1984; Goel, 1995) These models all mention an important design stage, the concept generation in early design. The main feature of this stage is the great use of drawing and the sketch (Purcell & Gero, 1998), for the sketch can concretize the design ideas. (Suwa & Tversky, 1997), communicating with the designer's inner thoughts. (Goldschmidt, 1991,1992,1994) Schon (1992) also pointed that drawing sketch is the reflective conversation with the situation. All the roles that sketch played in the design process is based on the studies dealing with concept generation by conventional media such as papers and pencils.
Today, however, the computer becomes more and more important in design process. It's not only used in the late design process as kind of simulated and presented media. There are many studies starting to find out how it affects the early design process, the concept generation. (Verstijinen et al, 1998; Kavakli et al, 1998). These studies start from different viewpoints: first, the cognitive viewpoint, through studying the designers’ behavioral structure and mental process during progressing the concept generation by conventional media, find out the insufficiency of media now; Then, studies work on developing computer-aided design system for design ideas. (Elsas&Vergeest, 1998; Gross, 1996) It is the applied studies on media; at last, the science of artificial intelligence also start probing the possibility using computers in creative activities, and pointing out that in many ways, computers are better than conventional media such as great counting activity, memorial space, and visual-feedback function. These features can offer designers broader conception space to explore, becoming the source stimulating design creativity. (Boden, 1998)

These studies show that computers can be applied to early design process working on concept generation (Won, 1999), and computers have some specialties superior than conventional media that they can be used to assist and stimulate creativity; however, Is applying computers to concept generation the same as using conventional media in the design-thinking process? If not, what's the difference? Then, can the merits of computers related to human work on the early design stage? What difference could happen? According to these questions, the goal of this study is to probe the different thinking phenomenon produced through concept generation by computers from by conventional media, and the effects of the development and presence of design concept generation resulted from the merits and features of the computers themselves.

2. Review

2.1. THE DEVELOPMENT OF DESIGN THINKING

Design thinking is coming from the research of cognitive psychology and cognitive science, trying to understand the behavior and inner thought of the designer. In 1970's, Eastman began to use scientific methodology and thus he opened the field of design research. In decades, there are lots of researches concerning about design thinking. With the maturity of this realm of research, design thinking is gradually becoming a discipline. (Akin, 1993). When solving a problem, the logic of inner thought and the progress of decision are the major topic (Rowe, 1992). The design problems are different from the usual ones, they are kind of ill-structure problems. (Simon, 1973). And they involve in the highest part of humankind cognition. (Cross et al.1996)
There are two typical viewpoints in the realm of design thinking: one defining design as a "rational problem solving process", and the other is defining design as a "process of reflection-in-action". Dorst and Dijkhuis (1995) point out that concept generation belongs to the last one. Since 1990, most researches of drawing sketch also stand for this thesis. And they put the emphasis on the phenomenon of visual thinking.

Concept generation is the consequential and important stage of design. (Jones, 1970, 1981; Archer, 1984; Pahl & Beitz, 1984; March, 1984; Goel, 1995). The most important character of this stage is the use of lots of drawing and sketch. (Purcell & Gero, 1998)

2.2.  SKETCH AND CONCEPT GENERATION

Sketch takes an important part in the process of design. For the reason that it provides and assists the possibility of visual thinking. Larkin and Simon (1987) point out a view in their research: A chart or a diagram may be better than ten thousand words. It explains the importance of visual thinking.

Goldschmidt (1991, 1994) is of the opinion that when a designer drawing a sketch, instead of revealing the image in his mind, he tries to create visual display. And thus bring out the image of the entity. Designers use imagery to form a new combination of gestalt. In the same way, they draw sketch to inspire the imagery of gestalt. Its character is the systemic exchange between conception and figure. And they are performed by two ways: One is "seeing as", and the other is "seeing that". The former means that designers use figural or gestalt to demonstrate the interaction between drawing and thinking; the later use the non-figure method.

Schon & Wiggins (1992) bring up an idea that design is a circle model of "seeing-moving-seeing", which is based on the protocol analysis study assignment of the architecture department students. Designers work depend on a media (such as drawing on the paper) to "seeing as" what they produce. And then they will go on the next action. They also put a definition on the unit of design process: a move experiment contains three kinds of "seeing": 1. literal visual apprehension; 2. appreciative judgments of quality; 3. apprehension of spatial gestalts.

2.3.  THE DEVELOPMENT OF COMPUTER MEDIA

The researches which study about the rule of sketch and characteristic visual-thinking are based on the conventional media. Today, computer enthusiastically involves in design process: Formerly it was a simulating and presenting tool, but now, the researches of computer aided concept design have largely developed.
Elsas & Vergeest (1998) mentioned about the superiority of using CACD in early stage: to promote or to improve the quality of design concept, to allow the high-speed production of design substitution, and to provide better communication and estimation. Besides, the early decision has a great influence on the cost of design, using CACD may avoid expensive and wrong decision. These researches emphasize on the development of computer system. They try to build up a drafting environment to gain the direct relationship between computer and sketch. Thus, designer can use computer to perform sketch test in the concept generation. (Gross, 1996; van Dijk, 1995)

On the other hand, some studies coming from the analysis of hand-made sketch. Attempting to apply it on the development of CAD. Herbert (1993) gave an example to explain the methods which can make CAD more effective, such as, to enhance the vagueness of figure, to increase the precision and recombination, to consider the relationship between sketch and out-let, and to improve the design interface. Besides, CAD can be more effective by using the memory function to mend the missing information, enhancing the fictitious operation, conferring the rules of coordinated system in CAD, and promoting the speed of drawing. These studies point out a new aspect of CAD.

3. Methodology

Nigel Cross (1999) retrospect some methods which use to study the essence of design thinking in recent years. There are five methods: 1. interview with designers; 2. observations and case studies; 3. protocol studies; 4. reflection and theorizing; 5. simulation trials. Protocol analysis is expanded from cognitive psychology. Newell & Simon (1972) apply it on the research of human problem solving process, since then, protocol studies become an important method in the field of design thinking. Nearly, it has vigorous development. (Goldschmidt, 1991, 1992, 1994, 1995; Schon & Wiggins, 1992. Akin, 1993; Suwa & Tversky, 1997; Gero & McNeill, 1998; Suwa et al., 1998)

There are two ways to gain the protocol data in design thinking field: think-aloud and video/audio retrospection (Suwa & Tversky, 1997). By now, there are studies which point out these two methods suit for different purposes. (Gero, 1999)

Nevertheless, the methods of studying computer media have no definite conclusion by far. Thus this research adopts think-aloud as the method to get protocol data, to encode, and to analyze.

3.1. EXPERIMENT

1. Topic: The design of reading lamp
2. Subject: At least 3 years working experience in product design; with the ability applying computers to design.
3. Tools: The subject prepares his own familiar computer media as the hardware and software. (The subject chose PRO-E to proceed design).

4. Process: Before the experiment begins to start, the subject should familiar with the skill of think-aloud. The requirements of this experiment are completing five to seven concept generation in about one hour, and requesting the subject to think-aloud while proceeding this design.

3.1.1. Preliminary results
The subject developed five conception generations as follows (fig1-5):

![Figure 1-5](image)

*Figure 1-5. Five conception generations of subject.*

The first and second conceptions take more time and are more complete. For the sake of limited time, the latter three conceptions are not so complete.

When using computer media to proceed this design, subject was asked to think-aloud. Sometimes it may happen that there were too much unnecessary comments, which is just the verbal of repeatedly command. And the complicated commands of the interface also lead to the result that the subject has no sufficient time to express the process of his thought completely.

Therefore, if we want to confer the deliberate phenomenon of computer media when proceeding a design, we really need a new method. Whether the video/audio retrospection may avoid the above-mentioned deficiency, or we need to develop a new method is the topic that we should investigate in the future.

3.2. THE ENCODING SYSTEM
This study attempts to probe the following problems: when using the computer media for concept generation, would the speculation mode of visual-thinking be different from using conventional media? And how does the characteristic of the computer media influence the design thinking process? According to the viewpoint of Goldschmidt (1994): Drawing sketch is a rational reasoning mode which coming from systematically interaction between concept and figure.

By using the computer media, in addition to reasoning between concept and figure, the designer must execute the commands on the computer to complete the action. This is quite different from the conventional sketch drawing. Therefore, the coding system in this study including three components: concept, figure, and operation. The definition of them as follows:
Concept (C): before the design action start, the initial idea of the designer, which is the basic idea of design. For example:

This design seems to be more streamline-shape like. (005)
Let's use tubular shape! (057)

Figure (F): means the imagery that inspires the designer to imaging or seeing. Imaging means that there appears clear imagery in the designer's mind, and "seeing" means that designer deliberate the image display on the computer, evaluating or taking action. For example:

How to draw? a rectangle, then add one more arc (077)?
Here is an acute angle. It's too sharp (084)

Operation (O): the designer executes the commands or enters the parameter, to accomplish the action. For example:

Here... put it higher. This side, push it more posterior, 150 (048)
Here, try... … 6, it should be OK. (025)

3.2.1. Results
Take account of the author’s ability and the amount of data for coding, this study only choose the former two concepts for coding analysis. The reason of choosing these former two concepts is that: The subject spends a lot of time forming the first and second concepts. However, due to the limited time and being exhausted by continuing speaking, the effective verbal data of the later three concepts (that is excluded the data of redundant commands) of the latter three concepts is quite insufficient.

After punctuating the verbal data of the first and second concept, we find out 38% of the verbal data is simply the command repeat. This part is due to using computer media. Since the author considers it is unrelated to the process of design thinking, it has been deleted. We only keep the effective verbal data for coding. The result as follows:

![Figure 6. The coding result.](image)

4. Analysis and Results
From the experimental process and coding result, we find several following phenomena:
1. In general, the subject would divide the desk lamp into three major component, base, lamp arm, and lampshade, to go on the design. Among the
five ideas, almost all the subject’s design following the order: lamp base → lamp arm → lampshade. That is, he process the concept generation of the lamp base first; then, according to that, he develop the lamp arm; finally joins the lampshade. This is corresponding to the thesis proposed by Manolya et al. (1998): most of drawing sketch is proceeding by a mode, "part by part". In other wards: no matter computer or conventional media, the behavior of drawing sketch both presents in a mode of designing by divided components.

2. When designing each component, the subject first has a crude idea (ex: the idea of streamline form, the idea of tubular form), then he start to design. In the designing process, the thinking mode of the subject is an interchange process between figure (F) and operation (O). After the subject form the initial concept, he start to execute the command (O) or to imagine which functional command to use to carry out the idea (F). There is no definite sequence between them. After finishing one component, the subject go on to form the ideas about next component; similarly, after the forming of the initial concept (C), then the interchange process between figure (F) and operation (O), till the component is completed. This process becomes moving in a cycle, which stop only when a design idea is accomplished.

3. In this study, because of parametric command of the computer media, the subject must manipulate parameter to concretize the design ideas, which results in the important action “operation” in this study. The reasoning mode which using the computer media for concept generation, basically corresponds to the viewpoint, proposed by Goldschmidt (1994), that the visual-thinking phenomenon is interacting between concept and figure.

4. The experiment also finds that: the particular “operation” of the computer media, would inspire the designer to find new figure (F). Take the verbal data in this study for examples:

   OK, it should be that, down, (063)
   Wa! What happened? Why it’s in the middle? (064)
   All right! That’s fine! Let us use three cylinders!
The original idea of the subject is to design two cylinders standing in the right side and left side. But after executing the commands, the cylinder unexpectedly showed up in the middle, So the subject changed his mind and turned it to be a design with three cylinders.

This situation is because of the property of the computer software, the designer usually need to enter a precise numeral to execute the command; however, the result may differ from what the subject has expected. When the differences does exist, the designer may try to put in a correct numeral again and again, till the result is compatible to what he has expected. But, in another situation, such differences would inspire the designer to get a new idea, then a new design form. This phenomenon is absent when using the conventional media.

5. Besides, the conventional sketch drawing permit the appearance of unconscious scrawl. Nevertheless, this phenomenon is absent when using the computer media. Because the computer software, like PRO-E, is characterized by the properties such as precise coordinates, reference datum, parametric commands. Each action is clear and definite. The user also is clear about each command he has made. Therefore unconsciously scrawl wouldn’t happen.

5. Conclusions and Future Studies

The computer media involving in early stage of the design has become a trend. And there are similarities and dissimilarities between the process using computer to progress concept generation and using conventional media. The study find that no matter computer or conventional media, the behavior of drawing sketch in both of them presents in a form of “by divided components”. The visual-thinking phenomenon found in the process of concept generation of the tester in this study, corresponds to the speculation mode, proposed by Goldschmidt (1994), that the visual-thinking phenomenon is interaction between concept and figure. Nevertheless, because of the characteristic of the computer media, there includes one more dimension parameter “operation” besides to the concept and the figure. The designer must complete the action through computer command. The concept generation becomes a speculating process between concept, figure, and operation, which turns into a cycle.

The peculiar “operation” of the computer media may invite designer to discover a new figure (F). Sometimes it may lead designer to overthrow the original concept and form a new one. This is what traditional media can’t do. Traditional sketching allow unconscious handwriting to happen, but this will not happen by using computer media.
This study focuses on the design-thinking phenomenon when using computer media to proceed concept generation. But there is no proper method to follow. Whether the video/audio retrospection can provide better verbal data, or we just need a new method, is really the subject that we should investigate in the future. Besides, owing to the deficiency of software, this experiment adopts PRO-E which is familiarized by the tester. The characters of PRO-E may influence the results of this experiment. The phenomena of design-thinking of the other kind of software will be lasted in remain discussion.

References