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ANALYSIS OF THE USE OF COMPUTER MEDIA BY EXPERT AND NOVICE DESIGNERS

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Abstract. This paper is based on an experiment of protocol analysis. In order to investigate the differences in models designed under various circumstances, the paper attempts to find out how expert and novice designers develop their designs with computer media. It also compares expert designers with their novice counterparts by analyzing and generalizing some cases in their thinking and designing process. Thus a designer who is very familiar with software and have expertise in design must apply different strategies to their design. This is indeed the cause of changes in the process of promoting from a novice to an expert designer. Therefore, the differences between novices and experts can be one of the foci of educating novice designers.

1. Introduction

The focus on theoretical models of computation in previous studies has already achieved considerable progress in the development of computer-aided design. However, an understanding of the behavioral thinking processes involved in developing more effective methods is now more and more important (Gero and Maher, 1993). While focusing on deeper levels of cognition, the current field on design thinking investigates the nature of problems by narrowing the focus of a particular problem. During the early stage of design, namely the concept generation stage, the importance of sketch and the significance of interactions between designers and their drawings have been progressively highlighted key features of this early stage are copious amounts of drawing behavior and the use of sketch (Purcell and Gero, 1998). The underlying reason for this is the crystallization of design ideas facilitated by sketch (Suwa and Tversky, 1997). However, previous sketch-related studies have invariably concentrated on experiments incorporating conventional media, whereas current research increasingly focuses on computer-aided concept generation (Tovey, 1994; Van Dijk, 1995; Lipson and Shpitalni, 1996; Gross,1996; Elsas and Vergeest, 1998; Won,1999; Wong, 2000).

The emergence of a new subject, computer media, brings into play multi-faceted impacts on conventional design. Because computers are used as a medium for design thinking, new impacts in creative design work emerge (Liu, 1998). Consequently, computers are increasingly recognized as an intervention in the early concept generation stage of the entire design process (Verstijinen *et al*, 1988; Kavakli *et al*, 1998). Various research results have already demonstrated that computers can be applied to perform concept generation in the early stage of the design process. Won (1999) suggested that differences in design presentation and the cognition of designers (using conventional and computer media) come from the independent characteristics of the different types of media. Using computer media, Wong (2000) presented several design thinking phenomena in the concept generation stage. Ho (2001) conducted experiments of conventional media to gain an understanding of the differences between experts and novices in examining strategies of solving well-structured design problems. No investigation, however, has been undertaken into cognitive behaviors of expert and novice designers performing concept generation using computer media. If we apply computer media directly to concept generation, would this have the effect of changing the design-thinking mode? Furthermore, when using conventional media, expert designers demonstrate a high degree of efficiency in their ability to solve design problems, but what are the observable phenomena in concept generation behaviors of experts and novices through a change in the media used?

Based on these questions, this study aims to discuss the emergent phenomena, or differences, when designers' thinking modes change through the application of computer media in concept generation corresponding to the inherent characteristics of computers. This is achieved by examining design ideas drawn from case studies of expert and novice designers. This attempt to understand designers' cognitive modes may assist novice designers in the process of becoming expert designers.

2. Review

How does a designer think regarding the design process? Among problem solving behavior theories, the search theory model introduced by Simon (1981) can be regarded as the most representative and important one. Recent scholarships have compared design with thinking. The most important approach in research methodology views imagery design elements as a research subject and method. In the design process, knowledge acquisition and representation, professional training, description and result presentation are all shown in the form of imagery. Numerous studies reveal that imagery is both an expression of a design concept and a thinking tool.

Consequently, studying drawing is regarded as the most efficient and effective approach of design thinking (Herbert, 1993). According to Goldschmidt, sketching is generally defined as a kind of one's ideas visual expression, although it can stimulate more ideas and new information during the designing process. Furthermore, she refers to thinking in designing as a figure-concept (Goldschmidt, 1994).

Studies indicate that a designer's experience is crucial to overall design. Experienced designers tend to make a decision instinctively when dealing with problems (Akin, 1984). Designers, who can deconstruct a phenomenon and render it the most economic and effective strategy, compile acquired knowledge (Waterman, 1985). However, numerous studies present different views. Lakin (1981) and Anderson (1981) indicate that during problem-solving expert designers tend to use a working-forward search strategy. Drawing from the process of problem solving in math and physics, they declare that experienced experts prefer the working-forward search strategy and procedural knowledge for problem solving. This strategy provides a clearer direction. Anderson's experiment also that experts tend to apply a breadth-first approach to problem solving, whereas novices adopt the depth-first approach. Ho (1997)'s research reveals that both experts and novices use a working-backward strategy for problem solving. Based on acquired knowledge and disciplines, they tend to start from the position against the assumption and obtain the result from much calculation.

Numerous important points exist within computer-aided design applications. Firstly, since computers are capable of copying, by integrating the cognitive design model into artificial intelligence, they can be trained to think as designers do. Secondly, since innovation is emphasized, computer media can be used to stimulate design thinking through examining computer operation as well as the interaction between different operations (Liu 1998). Currently, computers participate positively in the designing process. Many research has presented that they are no longer virtualizing design tools but a powerful assistant. Designers hope to accelerate designs or to make them more meaningful and workable with the help of computers. These studies attempted to develop a drawing environment powered by calculation so designers can test their drafts in the stage of developing ideas (Gross, 1996; van Dijk, 1995; Elsas and Vergeest, 1998).

3.Methodology and Steps

The research methods of this study are video/audio protocols and think aloud. These two methods were chosen to strike a balance between complete data and the whole effect since there is no confirmation of which protocol analysis approach should be applied to computer media research.

3.1 THE EXPERIMENT OF DESIGN THINKING

Notably, a pilot study precedes the formal experiment. Herein, both expert and novice designers developed two ideas. Moreover, there was no time limit and all the samples' protocol data were recorded throughout the session. Firstly, the designers' cognition to develop ideas via computer media was tested. Secondly, the collected data were decoded and analyzed.

The task of the experiment was to design an office chair with arms that rotated. The reason was that a chair has recognized function, flexibility in style, ability to suit other furniture, and is applicable to architecture. To avoid the error of constraining design thinking by using computers, the subjects, who required computers for design and aimed to develop ideas rapidly, were highly competent in IT skills, and familiar with [the selected] software. The expert designers in this experiment were trained for five and a half years in industrial designing. Alternately, the novice designers, who are sketch artists, have only six months' experience.

The experiment was conducted in a workplace where the samples were used and data collected without interruption. Mainly, computers as well as the designers' own equipment were employed. Since computer-aided design technology remains premature satisfactory CACD software does not exist . After consulting the designers, software selection was based on preference to provide the most flexibility. In this experiment, the experts chose 3D Studio Max, whereas the novices chose Form Z.

The results of idea development: the experts spent approximately two hours on developing design ideas (Figure 1 a, b); the time was measured as 0:53:17 for the first idea and 0:55:02 for the second. The novices spent approximately three hours on the two ideas (Figure 1 c, d); the time was 1:25:15 for the first and 1:11:08 for the second.

a b c d

Figure 1. a, b, c, d: The results of experts' and novices' ideas

3.2. THE ENCODING SYSTEM

Establishment of the encoding system is based on Suwa, Purcell and Gero's model, which contains physical, perceptual, functional and conceptual aspects (1998). The definition of the encoding system in this experiment

differs from Suwa *et al.*' s original model. That is, his model is based on conventional media, such as handwriting materials, while our experiment incorporates computer media applications. Computer media differs from conventional ones, which conceptual differences. The other concern is the validity of computer media. As visual validity is considered, evaluation relies upon perception, which is a crucial element in sketching that provides designers with concrete shapes for estimation, visualized by 3D drawing. Following Gero and Neill (1997)'s encoding system, the system herein was: conceptual (C), operational (O), perceptual (P) and evaluation (E). Although both encoding results were similar, they were valid according to the encoding definition. Furthermore, our segmentation is based on Goldschmidt (1991)'s segment, which was named design move. Due to the considerable amount of data, inappropriate data were excluded and both experts and novices were allocated one task. Data were encoded in the first thirty minutes of the task (Table 1).

TABLE 1: The coding of the data

	Protocol data	**C**	**O**	**P**	**E**	**Total**
Expert	Think aloud	6	11	9	7	33
	Video/audio protocols	10	14	10	10	44
Novice	Think aloud	5	20	9	12	46
	Video/audio protocols	7	20	16	10	53

In addition to the items in the original encoding system, this study adds nine sub-categories, which concerns with computer media, to the existing four categories. The reason for doing this is that the nine elements are able to provide accurate definition of the actions in the four categories. The consideration of computer media leads to adding the item of I-action to the sub-categories. Since the prompt presentation of ideas in computer media provides designers with immediate visual feedback, F-action and A-action are also very important (Table 2).

TABLE 2. Contents and definition of the codes

Category	Sub-category	Definition	Example
Conceptual	G-action	Set up goals and decide the design	Decide the design
	K-action	Recall the knowledge of designing	Recall or consult reference
Operational	D-action	Draw various elements	Lines, circles and logs
	L-action	Look at previous drawings	Shades, change the size and perspectives
	I-action	Features of computer operation	Combination, define standard features, correction (re-doing and erasing) and mark the size automatically
Perceptual	V-action	Visual features of the elements	Shape, size, texture
	S-action	The spatial relationship between the elements	symmetry, cut even
Evaluation	F-action	Relationship between people/nature and designs	Function and cost
	A-action	Aesthetic concerns	Good-bad, like-dislike

4.Analysis and Results

According to the video/audio protocol data, while developing a concept generation, the expert's actions reveal that new concepts keep welling out during the operational and perceptual processes and more new concepts are generated after evaluations. The generation of each concept turns to be more detailed and greater in depth with the designer's design knowledge and function considerations. The experienced designer is able to rapidly conceive a situation for the object to be designed and quickly progress to the concrete details from an abstract conception. Yet, the novice's actions show that after generating several concepts, he deliberates at the repeated comparison in the operational and perceptual processes. Accordingly, he make more evaluations and spends more time. Another difference from the expert is that the novice confirms the integration of his concept through figure evaluation.

In view of the think aloud behaviors while developing the concept generation with computer media, both the expert and the novice proceed with their designs constantly following the mode of conception, operation, perception and evaluation to conform to the operational feature of computers (Figure 2). There seem to be some differences with the expert, who tend to start the evaluation process right after one conception has been triggered.

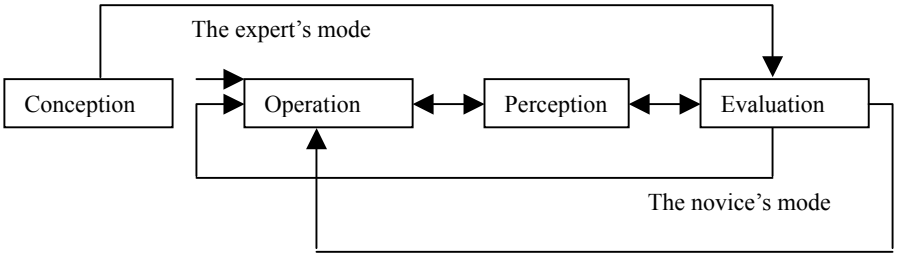

Figure 2. Thinking modes of the expert and the novice

With respect to the perceptual process, the novice requires more visual cues (such as features, shapes and sizes of the elements) than the expert. The novice confirms his next action after repeated evaluations on the visual features (Figure 3) based on the comparison of relationships between the features. But, the expert's visual considerations are attributed to the integrated elements that involve spatial relations and the relationships between figure elements and other elements.

Figure 3. Diagrammatic data of the novice's video simulation

During the design process, the expert builds up some of his problem and problem-solving plans at the same time. A skilled expert not only sets up goals and strategies at early stage of the problems; he presents the same at all stages. And, evaluations progressively escalate from the beginning to the end (Figure 4). Expert designers continuously assess their forecast results in the wake of the generation of visual information and new concepts. The design procedure therefore involves a great number of concept transformations or upgraded creativity.

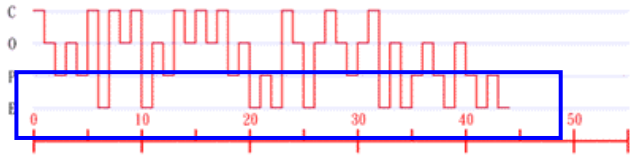

Figure 4. Video/audio protocol coding result of the expert

With respect to visual information, the expert designer is able to acquire many pre-restored design information out of his long-term memory (such as styles, functions and so on…). With this supremacy, the expert is able to spend less time progressing in concept development. The conception sketches, which experts rely on, are more like old information rather than thinking aids. The expert needs less external memory to aid his thinking process, as experiences accumulated through problem solving are already stored in his scheme. The novice, however, has less knowledge of design thinking process, and therefore needs more external (visual information) memory to aid his thinking. While the novice draws a new figure or shape, visual stimulation may appear through evaluations. Once the visual features of an object and their spatial arrangement bring about mode changes, the designer would be urged to proceed to the next figure without the visual features and unanticipated methods would be likely applied to generate potential cognition. Besides, the novice may leave the alternative concepts in the same window for comparison (Figure 5).

Figure 5. Diagrammatic data of the novice's design process

While designing each individual part of the object, both the expert and the novice start designing the details of one part right after completing the main structure stylization, and then proceed to other parts one by one. This corresponds with the theory raised by Kavakli (1998) and Wong (2000). As to the visual effects, the expert tends to decide the materials soon after finalizing the design of each part and further consider the relation of the designed object with the setting upon completion of the whole design (Figure 6). On the other hand, novices begin to consider the effects of material only after the whole design is completed (Figure 7). Of course, this can be taken as individual differences. However, it might be lack of experiences that impedes novices from considering the material effects and structure design at the same time.

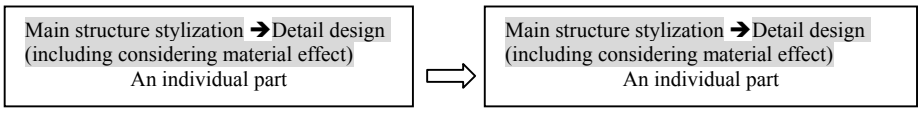

Figure 6. The expert's design procedure of an individual part

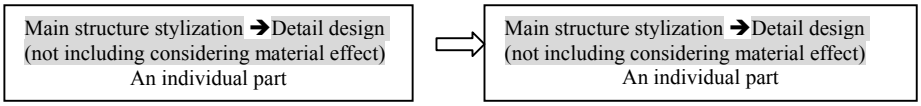

Figure 7. The novice's design procedure of an individual part

5.Conclusions and Future Studies

In this study, application of computer media and cognitive processes adopted by experts and novices have been preliminarily probed. Potential feasibility of computer media applied in concept development is once again evidenced. Applying computer media to help develop concepts enables both experts and novices to achieve the detail development faster, but at the same time cuts down the possibility of generating original and creative concepts. The merits of prompt feedback, constructional integration and operational process stimulate the designers to evaluate the possibility of modifications, and enable them to explore alternative types and notions. The design processes between those familiar with software packages and the real experts are different. A novice designer, during the process of becoming an expert designer, does display some transformations, or some differences. Novices from different backgrounds, adopting different strategies, transform themselves into experts and engage themselves into the design field. They make substantial contribution to the computer aided design and design education. Due to the broadness and enormity of data colleted and capability deficiency, only the first 30 minutes of each protocol report is adopted in this study. There might be some more differences that occurred in the middle and last stages of the design processes. Analysis based merely in a span of 30 minutes might miss some valuable aspects.

Computer media influence cognitively thinking modes of expert and novice designers. Researches reveal that novices are more creative than experts when applying conventional media to their concept development (Ho, 2001). Purcell and Gero (1998) also suggest that ambiguous and unorganized sketches be considered pivotal elements that affect design creativity. Yet, correlation between creativity and encoding system is not covered in this study and is yet to be explored in some future studies.

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