

Comparison of Designer's Design Thinking Modes in Digital and Traditional Sketches

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Abstract

The internal design thinking behavior of designers in the concept development has been an important issue of cognitive psychology. In this study, the design thinking process designers have in applying digital media and traditional paper in the early concept development stage was explored. Special focus was made on the structure and procedure of problem solving. With the verbal data obtained, the protocol analysis was employed to analyze designer's thinking behaviors in using different media.

From the study, the author had reached the following conclusions: (1) The proficiency and related knowledge designers have for the design project has a big impact on the construction of the design problem and the efficiency of problem solving and completeness of detail design. (2) Compared with the traditional way of idea development, digital media makes it possible for designers to have an in-depth description of the detail design with the help of related functions in digital media. (3) Designers can have an effective thinking process regarding the micro and macro aspects of a design project because of the function of software, enhancing the completeness of the design thinking while in traditional pen and paper environment, designers use the synthetic and contrast way to manipulate their idea development. The results obtained in this study will benefit both the design education and practical design activity where digital media is applied.

Keywords: *design thinking, computer-aided conceptual design, paper-pen sketching, Wacom interactive pen display*

Introduction

Regarding designer's design thinking behaviors, researchers concern about the clear presentation of the behavioral models designers have in the interior situation logic and decision-making process in their idea development (Rowe, 1987). During the design thinking activity, there are all sorts of variables and possibilities. Based upon the concept of information processing, Simon (1981) considers the design procedure a process developing from the initial state to the goal state, in which there are various searching paths and procedure. Therefore, the whole design procedure is often looked upon as a problem solving procedure. Schön & Wiggins (1992) claims that for designers, sketches not only serve as the descriptive tool for designers to record what within their minds but also a tool for designers to reinterpret the sketches previously made and to reorganize their concepts. The roles computer media plays in design can be divided into three layers, the design representation tool, design thinking media, and conceptual development tool. And different kinds of design media may result in different design thinking modes and representation styles (Liu, 1996). Currently, Wacom interactive pen display has made it possible for designers to make sketches right on the computer screen. As a result, the role of computer media has been promoted from previous representation tool and manufacturing assistant tool to the design thinking and conceptual representation tool. In other words, the role of digital media has been changed from the simple representation tool to one that can help designers with their conceptual development.

The purpose of this study is twofold: (1) to explore whether there are differences for designers to apply Wacom interactive pen display and traditional pen and paper in terms of their macro- and micro-strategies in their design thinking modes when they draw sketches for conceptual development; (2) with the diversity of tools provided by computer-aided conceptual design tools, is there a significant influence on the designer's idea development?.

Literature review

Design thinking

In performing design activities, all steps of design problem definition and the transformation of solutions are covered in the design thinking behavior. In such a design problem domain, problems can be divided into well-defined problems, ill-defined problems and wicked problems (Rowe, 1987). And because there is no definite end of the problem solving activity in design, we need to redefine the problem and process analysis and evaluation of the solutions if we expect to complete the design. Through the concept of information processing (Hayes, 1978, Newell & Simon, 1972; Simon, 1979), the manipulation of design problem can be referred to as the exploitation of knowledge state in the problem domain and the procedure of decision making. Furthermore, the input of knowledge state and the generation of the knowledge for feasible solutions construct the outcome of design thinking, from which the usable solutions can be evaluated and presented in the design output with the representation of new knowledge. Therefore, such kinds of external representations can be regarded as the concrete performance of designers in the design problem solution procedure.

Design sketches

During the design thinking procedure, the initial concept design is often considered the most creative design stage. In this stage, making design sketches (sketching) is the most

critical behavior. Many scholars claim that many prospective messages can be found from designer's sketches (Schon & Wiggins, 1992; Herbert, Goldschmidt, 1994; McGrwn et al, 1998; Suwa et al. 2000; Dorst & Cross, 2001), which can help designers to successfully develop their ideas. Therefore, designers usually present their proposals or generate their ideas by sketches. Due to different interpretations of the potential concepts, there are many views regarding the role of sketches in design, the major of which are : (1) seeing as (Goldschmidt, 1994), (2) moves (Schon & Wiggins, 1992), (3) lateral transformation (Goel, 1995), and (4) focus shifts (Suwa et al. 2000). In making design sketches, designers often use the episode knowledge, rather than theoretical knowledge, from their personal experience (Visser, 1995). Through such kind of "dialog procedure" of graphic media, designers can redefine or reconsider possible ideas and at the same time, take down possibilities of these ideas by the ambiguity and uncertainty of sketches.

Computer-aided conceptual design

Kavalki et al. (1998) point out that since 1965, when Sutherland proposed the interactive computer graphic system, all kinds of digital CAID tools have become more and more influential in the design process due to the rapid technical development in these forty years. CAID tools have become new methods for idea development, not just technical graphic tools (Jonson, 2005). In conceptual design, computer-aided conceptual design has become a new and important issue (Dijk, 1995). In the past, some studies had compared the differences between computer aided sketches and traditional pen and paper sketches in idea development. Because the digital tools cannot properly express the uncertainty of sketches in the idea development stage, all researchers report that the traditional pen and paper is better than digitalized environment in concept development. In light of this, it is more important whether the digital tools can reproduce the characteristics of traditional pen and paper sketches (Dijk, 1995). Though the digital tools were considered not appropriate for the concept development in previous studies, scholars also pointed out that in the use of digital tools, there existed differences among designers (Bildal & Demirkan, 2003). Nowadays, Wacom interactive pen displays can provide ways to help with design concept development similar to those in the traditional pen and paper environment. In addition, because of the diversity and recording ability of software tools, the digital tools may have different impacts on the concept development from the simple pen and paper tools.

Protocol analysis

Protocol analysis has been applied in multiple scientific domains, especially in cognitive science and linguistics. In design research field, the technique of protocol analysis has been adopted to help analyze the designing activity (Cross, 2001; Gero & McNeill, 1998; Cross, Christiaans, & Dorst, 1996; Someren, Barnard, & Sandberg, 1994; Ericsson & Simon, 1993). According to Cross (2001), Protocol analysis is flexible in the analysis of the forming of design problems, the generation of solutions, and the usage of design strategy in design process. Protocol analysis is composed of the following steps: design hypothesis or observation trend, experimental task design, subject performs the task, generate materials in the experiment, specify the coding scheme, process content coding, analyze the coding, and infer possible conclusions (Ericsson & Simon, 1993; Gero & McNeill, 1998).

According to the experimental procedure, there are two kinds of protocol analysis: concurrent probing and retrospective probing (Ericsson & Simon, 1993). The former gathers the subject's verbal data right on the task for analysis, one of which is the think aloud method; the latter collects the verbal data after the experimental task by recalling the behaviors the subject conducted in the task. For the completeness of the data

representation, the audio & video retrospection is often adopted. Though these methods of protocol analysis vary, each of them is effective in the collection and analysis of the subject's individual course of action. The difference between concurrent probing and retrospective probing is that concurrent probing is often helpful for the studies whose focus is set on the design procedure and more precise in catching the episode phenomenon whereas retrospective probing is concentrated on the design content and offers clues for recall (Dorst & Dijkhuis, 1995).

Method

Experimental methodology and procedure

Four designers with more than three years of experience were invited in the experiment. Among them, three used the Wacom interactive pen displays and Autodesk Sketch Book Pro while one used the traditional pen and paper tools. The same design project was conducted for four subjects. Furthermore, video and audio of the design episodes in think aloud were taken down by video shooting. In the experiment, subjects first had a 5-minute warm-up to get familiar with the think aloud procedure. After a short break, a 45-minute experiment was conducted. In the design task, subjects were asked to generate idea sketches for a portable MP3. In the limited time interval, they were asked to finish at least three or more complete conceptual designs.

Analytical method

With the data obtained, the authors process the coding for analysis according to the questions to explore in this study. To explore the features designers have in digitalized and traditional pen and paper environments and the influences two kinds of media have on designer's searching strategies for their design thinking, two coding modes: F-B-S and Fw-Bw were adopted.

F-B-S coding mode (Function, Behavior, and Behavior schemes) is primarily used to analyze the intentions designers have in dealing with the design problem domain. Two orthogonal dimensions for the representations reflected from the whole design behaviors can be divided into the intention of inference and the depth levels of inference. In the intention of inference, it is categorized into activities of function, structure, and behavior. Activity of function refers to the intentions designers have for the inference of functional problems in the design project; activity of structure is the manipulation of the product structure and the hierarchical relationships among parts; activity of behavior represents the actions designers have for the process or procedure in operating the product. On the other hand, the depth levels of abstraction of inference signify whether the designers are thinking about the whole product or only the details. The codes of five depth levels of inference and their descriptions are listed in Table 1.

Table 1
The coding of problem domain used in the design episodes.

<i>Coding Schemes of Problem Domain for Design Episode</i>		
Function, Structure, and Behavior		
Abbr.	Code Name	Descriptions
F	Function	The designer is reasoning the relations with the function aspects.
S	Structure	The designer is reasoning the relations with the structure aspects.
B	Behavior	The designer is reasoning the relations with the behavior aspects.
Depth levels of abstraction		

Abbr.	Code Name	Descriptions
R	Requirements	The designer is redefining or modifying the initial requirements.
0	System	The designer is considering the whole system.
1	Interactions	The designer is considering the interaction between the sub-systems.
2	Sub-systems	The designer is considering the details in a part of sub-systems.
3	Details	The designer is considering the detailed workings of a sub-system.

Fw-Bw coding mode (Forward and Backward schemes), on the other hand, is used for the behaviors of designers in the search and manipulation of problem solutions, which can be seen as the manipulation of micro strategies. Based on the abstraction levels of F-S-B coding mode, if the problem solution starts from a higher level of abstraction (of smaller numerals) to a lower level of abstraction (of bigger numerals), it is a Forward working (Fw) strategy. If it is in an opposite direction, then it is considered a Backward working (Bw) strategy. The coding and descriptions for Fw-Bw mode are listed in Table 2.

Table 2
The coding of micro strategies used in the design episodes.

<i>Coding Schemes of Micro Strategies for Design Episode</i>		
Working Forward Strategy and Working Backward Strategy		
Abbr.	Code Name	Description
Fw	Working Forward	The designer starts to search solutions form lower level of framework to higher one.
Bw	Working Backward	The designer starts to search solutions form higher level of framework to lower one.
	Strategy Continuing	It does not fill codes and keep blank when the designer does change the strategy.

Results and discussions

The design thinking mode for designers in the digital medium group

The results of protocol analysis reveal that three designers (Designers A, B, C) in digital medium group use Fw design strategy for different ideas and the analysis of sub-problems in different hierarchies as well as related solutions to the design problem. In the design thinking of the whole design problem, Designer A started all of his three ideas from conceptual problems on level 0 abstraction, then developed into details on level 2 and level 3, and switched back and forth between levels 2 and 3, solving the sub-problems repeatedly (refer to Figure 1). In the cases of Designer B and Designer C, they started their ideas from level 0, then developed into details on level 1 and level 2, and finally switched between these two levels for the solutions to sub-problems. In developing the first idea, Designer C started from the previously set conditions but an evident phenomenon of Bw strategy could be found in his further development. For example, the original specification of big screen was taken into second thought due to the inconvenience in hand-holding operation and finally a support frame was added to set the MP3 on the desk. Such kinds of conditions not set previously appeared and brought forth the backward working strategy for reconsideration, modification, or evaluation. This phenomenon may be partly due to the fact that Designer C's major was furniture design and the task was a project of 3C product design. Though Designer C had no problems in dealing with conceptual sketches and digital graphic tools, the subject was unable to

subtly take into consideration the whole problem and other related design conditions because of limited techniques and know-how knowledge regarding the experiment, resulting in the frequently seen Bw thinking mode in making conceptual sketches.

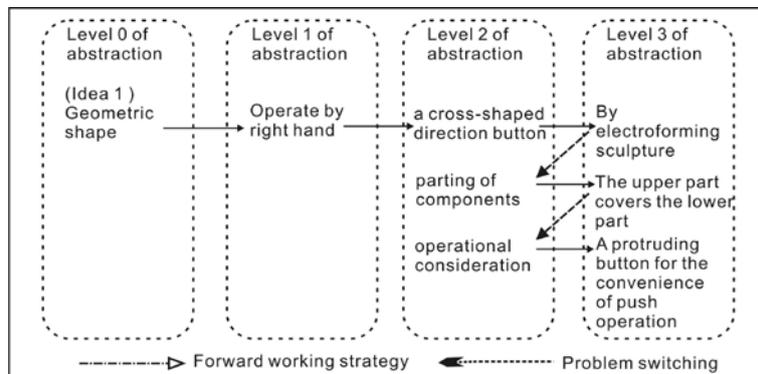


Figure 1
The procedure of the design strategy making of Designer A

The design thinking mode for designers in the traditional medium group

The thinking mode of Designer D was basically based upon the Fw design strategy. After the core concept was generated, his ideas started from level 0 or level 1 in degrees of abstraction on the basis of key technique and concept set on his own; then the design of details on level 2 and level 3 deployed. The situation of Bw design strategy happened only when Designer D was working on Idea 2 for the earphone port connection device (Figure 2).

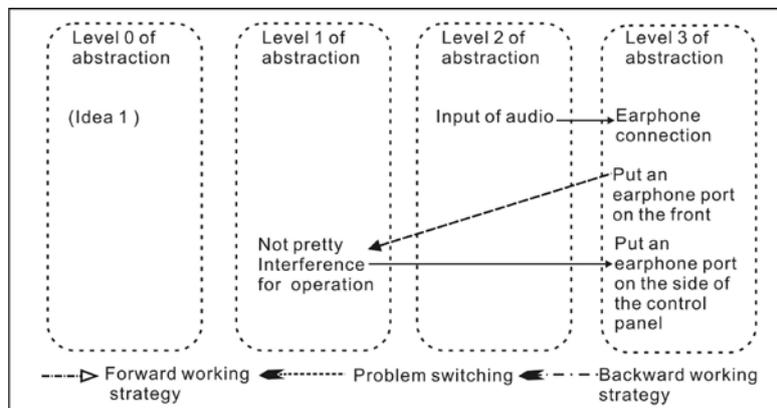


Figure 2
The procedure of the design strategy making of Designer D

After Designer D finished three ideas, it could be seen that all ideas were put on the desk for the evaluation of strengths and weaknesses. Such kind of synthetic evaluation and revisions was not seen in digital tool group. After this, the detail design, form modification, auxiliary graphics and descriptions of Designer D showed many Bw design strategies. In these steps, the conditions were not previously set but refining of the ideas and supplementary details with sophisticated design methods. It can be seen a strategy to add the related design conditions.

Discussions

Compared with the traditional pen and paper environment, digital tools do not have a critical or more evident influence in the speed of idea generation and the control of solutions in concept development. However, the differences in tool features cause apparent discrepancy in the detail development and consideration. Their differences are discussed from the function provided by media, transformation modes of concept development, and detail manipulation.

Function provided by media: The digitalized environment can offer more integral function commands than does the traditional pen and paper environment. Therefore, in the procedure of sketches, digital tools can offer visual ambiguity other than lines, helping designers to find more possibilities in concept development. In addition, the “undo” and “redo” function helps a lot for designers to switch between different levels of abstraction.

Transformation modes of concept development: Because of the features of media tools, designers under the digitalized environment are able to take advantage of the concepts of layer and duplication. They can compare the concepts on the semi-transparent upper and lower layers for a further extension of their concepts. On the other hand, designers in the traditional pen and paper environment will compare their ideas in an over view way in a big space to extend their concepts.

Detail manipulation: Because there are no duplication or zoom in – out tools in traditional pen and paper environment, for the manipulation of details, designers need to redraw the detailed parts. On the paper, designers can compare and contrast ideas on different levels of abstraction. For designers in the digitalized environment, they can include all details in their ideas with the functional commands in the system, presenting a better completeness of design proposals.

From these discussions mentioned above, it is clear that though there exist differences between two media tools, they can offer different advantages for designers in idea development. Currently, the digital environment is getting mature and designers can choose to use pen and paper or digital tools for their idea sketches according to their characteristics and habits in concept development.

Conclusions and suggestions

Conclusions

The design thinking modes of designers in applying digital medium

1. The contents and delicacy of pen touches of three designers in digital tool group are similar to those in traditional pen and paper environment. It is, therefore, inferred that the digitalized environment can simulate the sketching procedure in traditional manual tools.
2. In concept development, three designers in digital media group primarily adopt the forward working mode in searching for solutions to the design problem. Whether it is in a development mode with the priority of depth or of width of the design problem, designers build up their design problem structure by their technique and know-how as well as the design characteristics set by their subjective points of view. If designers can control the key technique and know-how, then they are more likely to adopt the Fw design strategy for the concept development; otherwise, if they are not sufficient enough in the control of the key technique and knowledge, it is more often to see the Bw design strategy during the concept development.
3. The commands offered in digitalized environment can make it possible for designers to have in-depth consideration of the product details.

Comparison of designer's design thinking mode in using digital and traditional media

1. It has been found in this study that designers have similar searching procedure in searching design strategy in applying digital and traditional media. The reason is probably that designers with years of experience have the same problem solving procedure in their design activity. No remarkable differences are found between different design tools or between design professions.
2. With traditional design tools, designers cannot push their thinking of design problem to a higher degree of abstraction. In other words, because of the limited space on paper and no redo or modification of the pen touch, the sketches look messy. Moreover, designers who use traditional pen and paper cannot make the detailed design as efficiently as designers in digital tool group.
3. Designers can process the comparison of ideas on different levels of abstraction due to the real-time over view feature in traditional sketches. Designers, therefore, can advantage of this feature on the synthetic transformation of concepts and idea modification. In digital tool environment, such kind of feature is restricted due to the limit of system and equipment.

Suggestions

In this study, the differences of design thinking modes experienced designers have in using different media are explored. Whether the application of different tools has an impact on designer's creativity is not covered. However, the designer's creativity will indeed influence the problem solving and self-evaluation of the design problem. In addition, for the design thinking mode of designers, only searching strategy and decomposition strategy for design problem domain are explored in this study. In the future, the structural reorganization of design problem and recombination of related design problems in design thinking can be further explored in the future.

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