DYNAMIC COGNITION AND CREATIVITY IN DESIGN THINKING PROCESS

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Abstract

The aim of this research is to understand human creativity, in order to contribute to computer support systems for both design and design education. For that purpose, the author has investigated the design thinking process. Creative thinking works as a dynamic process, which can be represented by thinking path models. 'Semantic generation' is an extremely important phase in design, based on the results of observing the behavior of designers. Also, interpretative searching for metaphors or associations with drawings can be effective in integrating the functions and images in a transforming process. The author describes 2 other experiments, building upon previous research into the drawing process of designers. By observing behavior of designers, relationships between the creative thinking and drawing processes were examined and features of designer thinking were characterized. A dynamic cognition process of design thinking could be represented by a model, with multiple paths among phases in a sequence. This model was proposed and tested, then discussed in terms of the clues it offers about design creativity.

Keywords: Human creativity, Creative design, Process modeling, Empirical study, Design education

1. Introduction

1.1 Aims of research into design thinking

This study aimed to model the creative thinking process in order to understand human creativity, focusing on design creativity for the clues to understanding the mechanism of innovation it is likely to produce. Understanding mechanisms of the idea generation process in design thinking has great potential for not only determining factors involved in developing

human ingenuity but also in developing education methods for promoting creativity.

In this research, the author attempted to clearly define the meaning of human creativity in design from the viewpoint of non-verbal expressions corresponding to a semantic approach to the generation of meaning in visual images, on the basis of design experiments.

1.2   Methods

Nagai and Noguchi [1] [2] [3] illustrated models from the results of empirical studies. The models represented thinking processes of student designers. The aim of those authors was to trace the process of creative thinking, able to be represented as thinking paths, as they were likely to be important for capturing the sequence of creative processes. For that purpose, they performed design experiments to characterize the sequence of creative design thinking, with the results being presented as thinking path models of designers.

Based upon those empirical studies, this study attempted to characterize in more detail features of design thinking processes and re-examined the results of previous experiments, performed between 2000 and 2001. In this research, design processes were also observed, by gathering data from drawings on a digitized white board.

1.3   Background of the research and approaching to the creativity

A current research challenge is to make clear the relationship between creativity and cognitive psychology. Finke, Ward and Smith [4] [5] proposed the 'Geneplore Model' in 1992, which illustrates the basic structure of generative and exploratory cycles. The Geneplore Model is useful for understanding more logically behavior of designers in order to develop their creativity. For example, it was pointed out that 'the interpretative constraints should not be too general or too specific.' The results of experiments by Nagai and Noguchi fit into this theoretical consideration. In particular, subjects exhibited high creativity when they had been given keywords, which were difficult to directly equate with form. Nagai and Noguchi found that there were several different paths to producing visual images from difficult keywords (Fig.1). They concluded that it was important to give an adequate abstract level of difficulty in the hierarchical structure of the meanings of the keywords.

Keywords were able to stimulate the creativity of subjects, however Finke *et al.* also described that '… the resulting structures tend to be less conventional and more ambiguous and display emergent features that can be utilized during creative exploration'.

The research by Finke *et al.* was based on laboratory experiments using students, with a top

down method and logical analysis from the Geneplore Model. However, their research also focused on expertise in design creativity.

Expertise of design thinking needed to be investigated by long-range observation. Candy and Edmonds observed an expert designer's creative process and formulated computational models [6]. They also showed cognitive models of co-creativity between artists and the technologists [7] in order to construct a communication model for more creative human - computer interaction.

Cross and Cross [8] [9] illustrated formulation models of strategies employed by professional designers. In this research, they focused on designer activity, which required not only specialized skills but also more basic and common abilities.

This author asserts that a bridging between the scientific and logical type of approach used by Finke *et al.* and empirical studies like those performed by Linda and Edmonds is required and therefore that bridging was attempted in the research for this study.
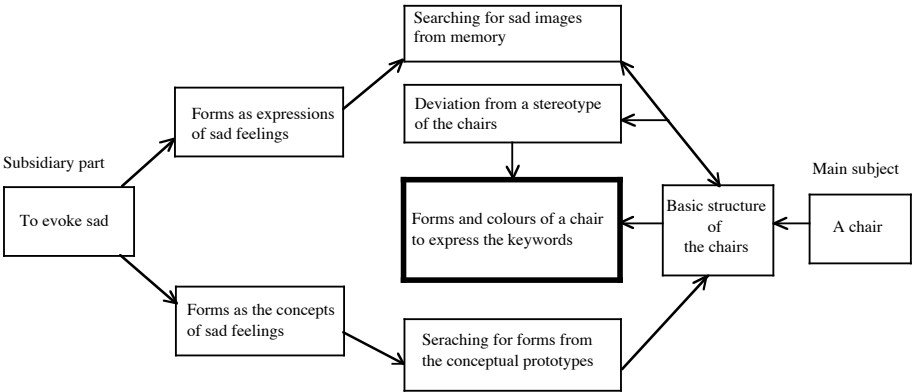

Figure 1: A model of the multiple thinking paths in design of 'sad imaged chair'

2. Experiments and observation

2.1 Drawing processes

Goldschmidt [10] pointed out that drawing processes are significant indicators, that are central to understanding features of the creative thinking process from observing the design process of architects.

Nagai and Noguchi have been approaching the creative thinking process in design since 1999.

Figure 2. Examples of drawings on the task to image the 'undiscovered plants'

Initially, they focused on the design process as a transforming process from keywords into forms. They carried out experiments to extract features of the creative thinking process of designers. By observing the behavior of designers, they concluded that the types of drawing processes gave significant clues to understanding the structure of creative thinking and thinking modes of designers (Figure 2). Using 80 subjects, the characteristics and generation process for their drawings were classified into 4 types. Results of evaluation of the drawings, demonstrated that the evolving type was distinguishable from the other 3 types. The evolving type exhibited high abilities for form creation and high skills of expression (Table 1).

This study equated the drawing process with a model, an assumption from previous research on designing processes, as a transforming process from keywords into visual images.

Table 1. Number of samples in each quadrant of the principal components space

(axis x indicated creativity, and axis y indicated ability of visual expression)

	Relaxiation					Excitement				
	Quad I	Quad II	Quad III	Quad IV	Total	Quad I	Quad II	Quad III	Quad IV	Total
Evolving type	6 (0.46)	3 (0.15)	0 (0)	2 (0.11)	11	6 (0.4)	1 (0.07)	0 (0)	4 (0.2)	11
Diveging type	1 (0.08)	11 (0.55)	10 (0.67)	9 (0.47)	31	3 (0.2)	12 (0.86)	9 (0.56)	7 (0.35)	31
Adhering type	6 (0.46)	5 (0.25)	1 (0.07)	2 (0.11)	14	5 (0.33)	0 (0)	3 (0.17)	6 (0.3)	14
Poor imagination type	0 (0)	1 (0.05)	4 (0.27)	6 (0.32)	11	1 (0.07)	1 (0.07)	6 (0.28)	3 (0.15)	11
Total	13	20	15	19	67	15	14	18	20	67

2.2 A model of the design thinking path

Noguchi performed empirical studies on the role of material constraints in creative design thinking [11]. Nagai and Noguchi performed another design experiment in order to understand the real-time process of designing, by monitoring student designers [2]. From the results of that experiment, they found a common denominator in all subjects, however the subjects showed different individual thinking processes. This process is schematized in Figure 3.

Based on this experiment, they asserted that subjects thought of design purpose as binary, with a main part and a predicative part, in the early stage of design processes. At the next stage, which they named 'semantic generation search', subjects connected these 2 paths when they attempted to adjust functions and form of the design object. In this phase, design constraint effects had an important role in generating forms. For the former and latter parts, thinking paths were driven into different modes. They also determined that a 'pre-drawing action' was evident in all subjects. This may be an important clue for understanding designer creativity.
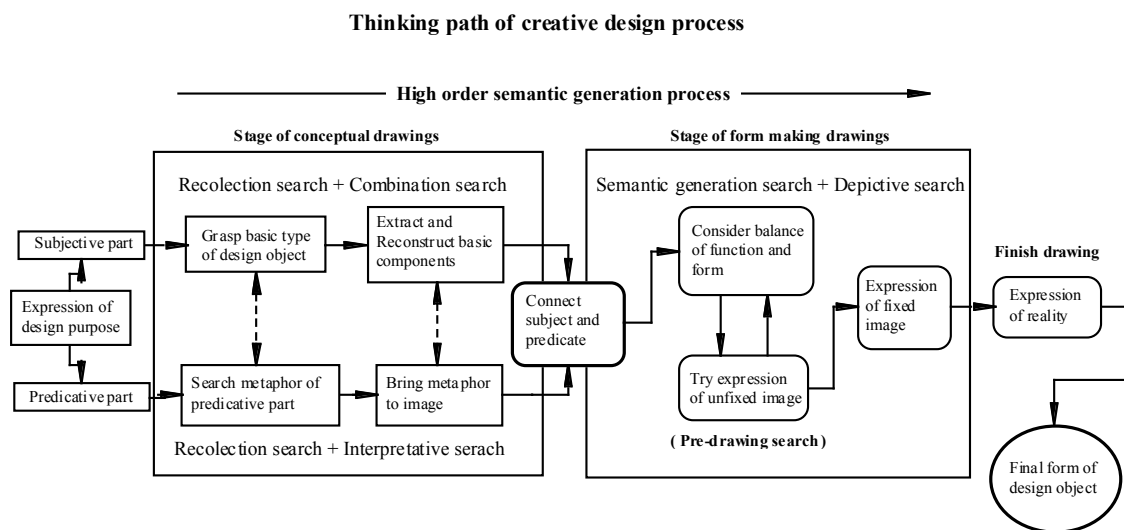
Thinking path of creative design process

Figure 3. Thinking path model in creative design

2.3 Pre-drawing action

Nagai and Noguchi discussed that the pre-drawing action of subjects is related to their memory (2002). This study aimed to confirm the role of pre-drawing action using another experiment. The experiment was conducted at Loughborough University, in August, 2002. A subject with 10 years experience in product design, had their drawing process observed. Another subject that did not have experience as a professional designer was also observed, for comparison to the expert designer.

Subjects were assigned drawing tasks and also asked to speak out ideas as they passed through their mind, whilst doing the tasks. Position data were collected on a white board from a drawing pen, digitized and input into a computer. Then data were plotted onto line graphs, with 1/100 second interval points. Tasks were formed in a set of 4 sessions. First, the subject was assigned a task to draw a teacup. The second task was to draw a teacup remembering the subject usually uses one. The third task was to make a new shape for a teacup. The fourth task

was to design a teacup for a friend of the subject. The experimenter recorded the subject's behavior using a video camera and gathered position data for each drawing. The experimenter measured processing time for drawing. Behavior was observed. particularly concentrating on the re-drawing action for each task. The experimenter collated the behavior of the 2 subjects in order to find common elements in these drawing processes.

Both subjects started drawing immediately after assignment in the first task, but they needed the longest time to start drawing for the fourth task. 'Pre-drawing action' was observed in the fourth and third tasks. In the third task in particular, this was observed frequently and subjects repeated it in a few minutes. Results suggest that the pre-drawing action indicated the subject's thinking mode in the sequence and is related to the abstract level of design thinking.

Figure 4. Digitalized drawings on a whiteboard on session 1 to 4 (from left hand side)

Figure 5. Data on axis-x (left) and axis-y (right) of the subject's drawing in the session 3.

A common sequence between drawings from artists and the drawings from designers is that they start rough drawing on paper to decide composition and then go on to draw shapes, forms, positions, shadows and so on. Finally they complete with fine drawings. That the pre-drawing action had been observed, particularly at the phase of form making, suggests that the subject recalled images to correspond with the design goal description from memory. It appears as if they pulled images from stacks in their memories by synthesizing mental imagery with pre-visualized images. Also, throughout monitoring of the previous experiments, metaphors could be extremely effective in breaking mental blocks and design fixation in the creative thinking process of subjects.

2.4 Observation

In order to examine more details of the process of creative thinking, a second design experiment was performed. One subject was the same person with 10 years experience as an in-house designer used in the previous experiments. This experiment was performed in November, 2002. The subject was assigned a task of designing a wearable tool to communicate for the hearing impaired. The subject started to write down the keywords related to the task and tried to make the concept clear.

At the first stage of the task, another person was assisting the subject as a companion, as in an assistant designer. Talking with the subject was allowed but leading was inhibited for the assistant. For approximately 40 minutes, the subject diverged the ideas in discussions with the assistant. Whilst discussing with the assistant, the subject sometimes drew sketches to illustrate and explain the ideas. In the early stage, the subject and assistant interacted about the keywords, 'wearable' and 'communication tool', then the subject made notes with illustrations. The subject drew a form of the object and added an explanation about how to wear and use it, what mechanism it had, and how to communicate with other people. After 30 minutes, the subject started to elaborate with drawings and modifications. The subject seemed to develop the ideas with the drawings on paper quickly.

In the second stage, the experimenter gave a cue to stop the interaction between the assistant and the subject, then the subject was asked to decide on a final sketch design. The subject turned from the assistant and concentrated on drawing, stooping over the desk. After 20 minutes, the final sketch was finished and the subject said it was not complete but could do no more in that session. Throughout the experiment, 9 idea sketches were created, with 2 of them evolving into a new design. The experimenter captured the subject's behavior and distinguished the elements in the second stage from the first stage. Drawings in the first stage showed characteristics similar to the drawings of a divergent thinking type in previous experiments by Nagai and Noguchi in 1999. However, drawings in the second stage were obviously different from those in the first stage. The second stage drawings were the same as drawings from the 'form making process'. The subject seemed to switch thinking mode from interpretative understanding into exploring by schematic reasoning to find semantic meanings in order to generate forms of the design object.

2.5 Discussions

From the observations, the subject's behavior and phases of the drawing process were examined to understand design thinking processes. The subject had the framework, which was

formed from personal knowledge obtained through personal experience. To drive the creative thinking process in design, it is important to have un-visualized images and to express them in drawings. Pre-drawing action can be performed as part of the functional clues to emerging inner images, which have been pulled from memory. There are 3 main phases in design thinking and they dynamically influence each other. The first phase is an interpretative process, which is based upon linguistic understanding. The second phase is a re-structuring process in order to re-frame personal knowledge. The third phase is a generation process. In this last phase, drawing worked as a highly effective process for determining semantic meanings to correspond with the form of design objects. In summary, creativity can be related to the flexibility of re-structuring frameworks of knowledge.

3   Modeling of design thinking

3.1   Understanding keywords

When designers were given design goal descriptions, they would make a purpose for the design process. By understanding that linguistic goal, they tried to drive design thinking to correspond with the images. Keywords were understood separately to the main part, which was design object and subsidiary parts. When the keyword as a subsidiary part was at a high abstract level and difficult to equate to form directly, designers needed to interpret the meaning by understanding sub-categories of the keyword.

3.2   Transforming processes

To investigate the designer understanding process for keywords, it was represented as a cognitive process. As a result of the experiments described above, the thinking path model represented in Figure 1 was modified to produce the model of a transforming process shown in Figure 6.
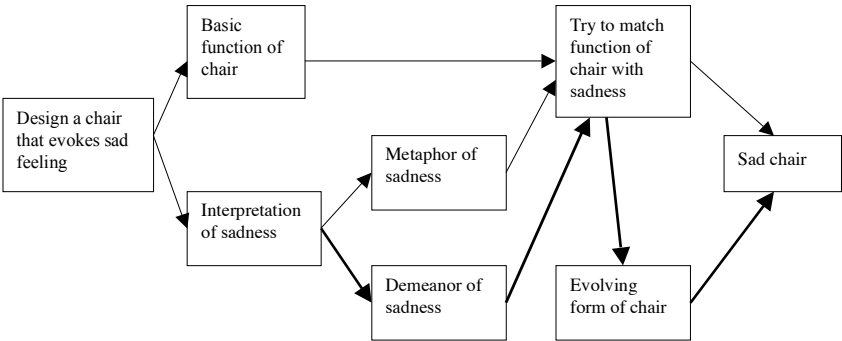
Figure 6.   Thinking path model in transforming process

3.3   Dynamic cognition process

The creative thinking process in design can be represented as a combination of flexible and variable structured processes. The thinking path model shown in Figure 3 was modified to produce the dynamic cognition process model in design shown in Figure 7. This model illustrates 3 stages of the creative process of designers: interpretative stage (including reconstructive searching phase), semantic generation stage, and finalization stage.
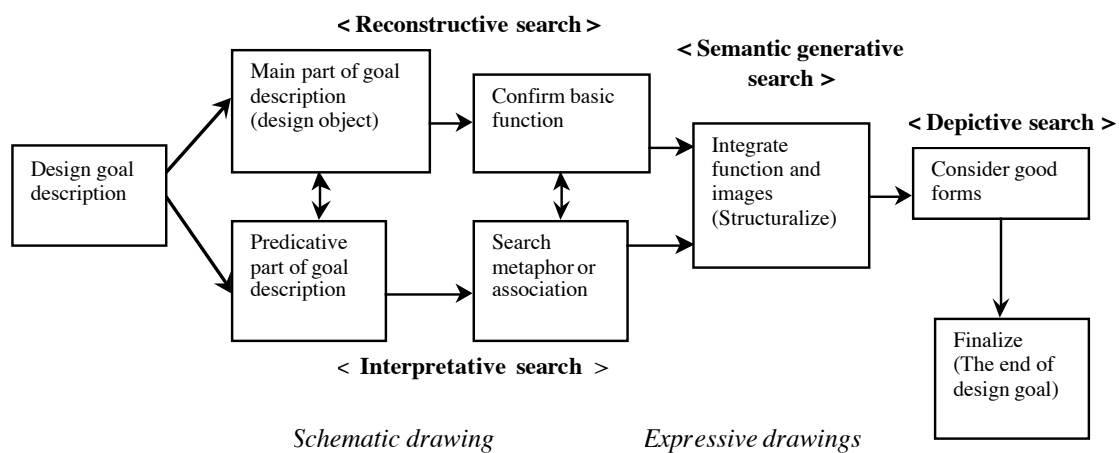

Figure 7. Dynamic cognition process in design thinking

4.   Conclusion

A framework for creative thinking processes in design was proposed, bridging cognitive research by Finke *et al.* and empirical research by Candy and Edmonds. From this a dynamic cognition process model of design thinking was presented. This model presents many clues for characterization of design creativity.

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