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# A STUDY ON THE THINKING PATH MODEL OF CREATIVE DESIGN PROCESS

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## 1. Introduction

Recently, researches on the creative thinking have been increasing especially in the field of design science.
In this flow, several researches with experimental studies have been made remarkable results such as Goldschmidt, Purcell and Gero, Dorst and so on [Goldschmidt 1991][Purcell&Gero 1998][Dorst 2001]. Before these researches, Finke, Ward and Smith made famous research on creative cognition, in which they had experiments of invention using several geometrical shaped parts [Finke, Ward & Smith 1996]. Those experiments had also been verifications of the "Geneproa model" which was hypothetical model of inventory thinking proposed by Finke. In their experiment, the subjects were observed in the tasks of combining the parts that resulted some inventive discoveries. Finke, Ward and Smith did not focused on the subject's drawings. On the other hand, Goldschmidt, Purcell, Gero and Dorst focused on the subject's drawings. However, their experiments were put emphasis on the analysis of subjects' protocols, and drawings were treated as a reference for the analysis of thinking process.
We assert that, in analyzing the design thinking process, to know creative thinking paths in the searching space is important [Maher, Poon & Boulanger 1996]. However, to do it, the observation should be put focus on the subject's drawing process and behaviors rather than the protocols. Because, in design experiment, the protocols often do not reflect the contents of subject's thinking process. In that case, the experimenter should slip into the subject's mind and should infer his/her thinking process as if the experimenter were dwelled in the subject's mind. The thinking path of creative design could be represented as a model by using this standpoint. In following sections, we introduce this experimental study.

## 2. Experiment

### 2.1 Procedure of the experiment

We think that the most generalized representation of design thinking process is translation of design purpose (expressed in linguistic mode) to visuo-spatial outcomes of it. Then, we had an experiment to know the real time thinking process in which designer translate the design purpose (expressed by words) to drawn sketches as the final ends.
The experiment was held at Musasino Art University between June and July of 2001. The subjects were 4 students of 3rd and 4th year of under graduate design course: 2 students from an engineering oriented university and 2 students from an art oriented university.
The each subject was, at first, assigned to design a "beautiful shaped" (we call this first keyword) tape

dispenser and after while (about 5~7 minutes after the start) he/she was assigned to make it “gives soft image"”(we call this second keyword) as a sub-concept of beautiful shape. Our intention of giving 2 staged keywords was that it might make easier to see how designer changes his/her thinking mode during the design task. The subject was given about 20 minutes to accomplish the assignment.
The subject’s behaviors during design task were recorded by two video cameras: one camera recorded drawing from over head of the subject and the other camera recorded the subject’s performances (including expressions and protocols) in front of the subject.
After finishing the design task, the experimenter conducted the subject to speak his/her thinking process under watching play backed video movie (retrospective protocols).

### 2.2 The results of experiment

We put the observed data together and analyzed each subject’s thinking process as follows.
(1) The subject 1: A 4th year student of art oriented university (visual communication design).
After started the task, he was sunk in thought about 40 seconds and fingered soft rubber eraser. Then started drawing with thin and weak lines then, in a moment, stopped drawing and erased it. He frequently repeated this behavior. After 1 minute and 40 seconds has passed, he started his first sketch with thin lines in not so quick movement. After 4 minutes have passed, his drawing was gradually changed to bold lined and put shade. After about 7 minutes have passed, he finished the first drawing and turned page of sketchpad. Then he started perfectly different sketch than the first one.
At this moment, the second keyword "soft imaged" was given from the experimenter and he stopped all movements. After a while, he started drawing and said, "Just I think it resembles to a snail" and turned the page of sketchpad. He moved hand and took aim at the sketchpad with untouched line (we call this “pre-drawing”). Again, he frequently repeated erasing and redrawing. After 13 minutes have passed, he started his 3rd sketch. He gradually drew a whale-like shape in frequently tracing lines. After a while, he started to deform the whale-like shape and redrew curved lines with changing proportions of the shape. After fixed the shape, he put shades to his sketch. After 18 minutes and 30 seconds have passed, he turned again the page and started to draw his 4th sketch. This time he drew quickly, elaborately and without erasing sketch. During the task, he did not make so many talking except when he explained some metaphors emerged in drawings. In the retrospective protocols, he took a lot of times to explain his thought on the functions of tape dispenser.
(2) The subject 2: A 3rd year student of art oriented university (visual communication design).
After started the task, she was sunk in thought a few minutes, and began drawing. After 4 minutes have passed, she concentrated to drawing. After 5 minutes have passed, she began 2nd drawing and seemed to be in deep thought while drawing. After 7 minutes and 15 seconds have passed, the experimenter gave her the second keyword "make soft imaged". After a few moments being sunk in thought, she started her 3rd sketch. After about 10 minutes have passed she started to draw her 4th sketch and at 40 seconds have passed she turned the page of sketchpad. Then, she started to draw perfectly different shape but suddenly stopped drawing and discarded it by cross lines. After a few minutes thinking, she started to draw perfectly different shape, then modified it into a shape like liquid drops. She concentrated to drawing this sketch until 15 minutes 40 seconds have passed. Then, she turned the page of sketchpad. Her final drawing was started with "pre-drawings" and drew similar shaped sketch as the 3rd one but in large scale this time. She finished final sketch with elaborate line drawings and shadings. She was almost very quiet during the task, but in the retrospective protocols, she turned to talkative. She made detailed explains about her drawings shown in video screen.
(3) The subject 3: A 4th year student of engineering oriented university (industrial design).
As soon as the first keyword was given, she started drawing. At right side in the page of sketchpad, she drew a lined frame, at first, and then began to draw basic shape of existing tape dispenser in it.
She drew next to next cartoon like sketches in talkative attitudes with quickly moving hand. After 1 and half minutes has passed, she gradually concentrated to drawing and became quiet. After 3 minutes have passed, she explained her sketches in answering the experimenter's question. During the explanation she did not stop drawing and sometimes added ideas into the drawing. After 7 minutes have passed, she became concentrated again after a moment of pre-drawing, and then she started drawing at slow speed. After the second keyword, she sunk in thought a moment and made quick pre-

drawing, then immediately started drawing. She made a number of sketches one after another rapidly, and seemed to generate the next idea during the drawing. She often generated new shapes by combining geometrical forms. At the final sketch, she used the eraser and finished it more elaborately. During the task, she had been talkative and seemed to be avoided stress by talking. Her attitudes were stable through the experiment and kept drawing continuously. As the result, she made the largest number of sketches (19) among 4 subjects.
In retrospective protocols, she spoke with not so many words concerning metaphors but spoke with words directly connected to geometrical forms in her 20 minutes talking.
(4) The subject 4: A 4th year student of engineering oriented university (industrial design).
After first keyword was given, several times, she made questions on the task, and then drew frame lines at first. She repeatedly drew thin lines on the frame lines and put shadings with rhythmically moved hand. She scarcely talked during the task except several times talked about trivial things of not concerning to the sketches. While she were in drawing, if the experimenter talked to her, she only responded "mm..." and never turned her eyes from the sketches. Every time before she drew new sketch, she did pre-drawing and then drew frame lines. When she moved to next sketch, she took a little thinking time, and then started to draw quite different form. She drew nicely varied sketches with big stroke and quick moving of pencil. As drawing was progressed to some extent, she sometimes tried to retouch and put brushing up to her sketches.
After second keyword was given, she had a few thinking time, then repeated pre-drawings and drew curved lines into an integrated shape. She scarcely erased her drawing but often reviewed her precedent sketches when she moved to draw another sketch. She seemed to be interesting to the task.
In the retrospective protocols, she talked a lot on her sketches connecting to some metaphors.

**Figure 1. The subjects' sketches (left to right: subject 1, subject 2, subject 3, and subject 4)**

## 3. Discussions on the method of analysis

### 3.1 Protocols did not indicate thinking process

In this experiment, we intended to know the designer's real time thinking processes but the subjects' protocols were perhaps not available to know it. The subjects were reticent when they sunk in thought and generating image of target object. In contrast, the subjects became talkative when they explained their sketches after finished the tasks. Usually, the protocol analysis put weight on the subject's talks and explanations. In that case, retrospective protocols were adopted as the most significant clues to know the creative thinking process. However, the retrospective protocols do not give real time thinking process They give only past explanations of the thinking process as the results of creative thinking. To know how creative idea was generated, the real time trace should be adopted based on the common basis of the subjects' thinking situations. Therefore, we needed another method to know their creative thinking process as follows.

### 3.2 Dwell-in observation

When we analyzed the subject's creative thinking process, we had to infer it by way of as if we were slipped into the subject's mind. We named this way "dwell-in" observation depending on the Michael Polanyi's words. Polanyi said that to understand tacit dimensions of one's knowledge, we needed to put our thought into one's mind as if we dwelled in it [Polanyi 1966]. To do this, the experimenter needs to have a common ground with the subject's situation. In this experiment, fortunately, the experimenters have experiences of design works, so that they could understand the subject's thinking processes with the "dwell-in" observation. To do the "dwell-in" observation, the experimenter should have similar experiences of the task, which is given to the subject.

## 4. The analyzed results

On the basis of the "dwell-in" observations, we analyzed the subjects' creative thinking processes as follows.

### 4.1 Two parts in the description of design goal

We inferred, as mentioned in another presentation, that designer usually recognizes the description of design goal as two parts: for example in case of design goal described as "Design modern chair", "chair" is recognized as the subjective word and "modern" is recognized as predicative word. Then, designer thinks separately of the subjective part and the predicative part of design goal.
In this experiment, we observed the subject's thinking process with keeping this thought in minds.
The design goal of this experiment was "Design beautiful shaped (and gives soft image) tape dispenser". The subjective part was "tape dispenser", and the predicative part was "beautiful shaped" and then "gives soft image".
From the observation of the subjects' drawing processes, all the subject of this experiment were seemed to think separately the subjective part and the predicative part of the description of design goal.

### 4.2 Searching modes observed in the experiment

Through whole tasks, we observed that the subject changed his/her thinking mode in several times.
In another presentation, we pointed out that there were two kinds of thinking modes: F (Form making) mode and M (Metaphor) mode. However, we found, in this experiment, that both thinking modes could be decomposed into more numbers of searching modes. Just after the first keyword was given, some of the subjects confirmed the subjective part (tape dispenser) of the goal description by drawing typical model of it. Then in next step, he/she searched metaphors by which he/she could interpret the first keyword (predicate part of the goal description). We can see it in the subject's protocols. We call this thinking process as "interpretative search". In case of the subject 2, she searched things connected with the keyword "make soft imaged" in her memory. We call this "recollective search". After this, the most of the subjects tried to decompose the parts of the prototype and recombined or modified them into a fitted form to the keywords (beautiful shaped and makes soft imaged) under considering that it could perform the function of tape dispenser. We call this process as "semantic generation search", because, translating keywords into image was the process of generating meanings. In case of the subject 3, she tried to make forms of tape dispenser by repeated recombination of the geometric forms. We call this "combination search". At the latter process of the design task, most of the subjects tried to figure out their internal image of designed object onto the sketchpad. We call this process as "depictive search". At the final stage, most of the subjects tried to refine and put shade on their drawings. This final process was not a searching process but the process of making up reality of drawings.

### 4.3 Pre-drawings as an important searching mode

We took notice on the pre-drawing actions of the subjects.
The subject often moved his/her hand as if he/she was drawing something but did not touch pencil on the paper. We named this action as "pre-drawing". Almost every time when the pre-drawing was emerged, the subject became reticent and seemed to be sunk into deep thought, and then he/she started to draw new shapes with thin lines but soon erased it. This action was repeated until the new form was fixed on paper.
We thought that when the pre-drawing was emerged, the subject was generating his/her new image of target object in mind but it was not fixed yet as a figure of being able to draw with clear outlines.
Therefore, we believed that the pre-drawing was the crucial key to know the creative thinking in design process. While doing the pre-drawing, the subject must have been searching clear image of, which was interpreted from the description of design goal. Although an image was in his/her mind, it was not so easy to decide the figure of the image. Then he/she repeated the pre-drawing and thin lined drawing with frequent erasing. He/She had no confidence to draw by steady and bold outlines. We call

this behavior of the subject as “pre-drawing search”. The pre-drawing search might be included in the depiction search, but it was important that the designer was searching a figure fitted to the design goal by moving his/her hand as if he/she were in drawing actions. It implied that the physical moving was needed to designer’s creative thinking process before getting visible form of design object.

### 4.4 Thinking path model as the trace map of thinking process

As the results, we tried to represent the subjects’ thinking processes as diagrams of thinking paths.
To do this, thinking process must be decomposed into several behavioral units. We extracted the subject’s behavioral unit not from observed outward appearances of them but from inferred processes of their inner sides.
We adopted the standpoint that we thought as if we were doing the same task as the subjects, and traced their thinking processes as possible as to have reality.
As the result, we presented a thinking path model of creative design process as shown in figure 2.

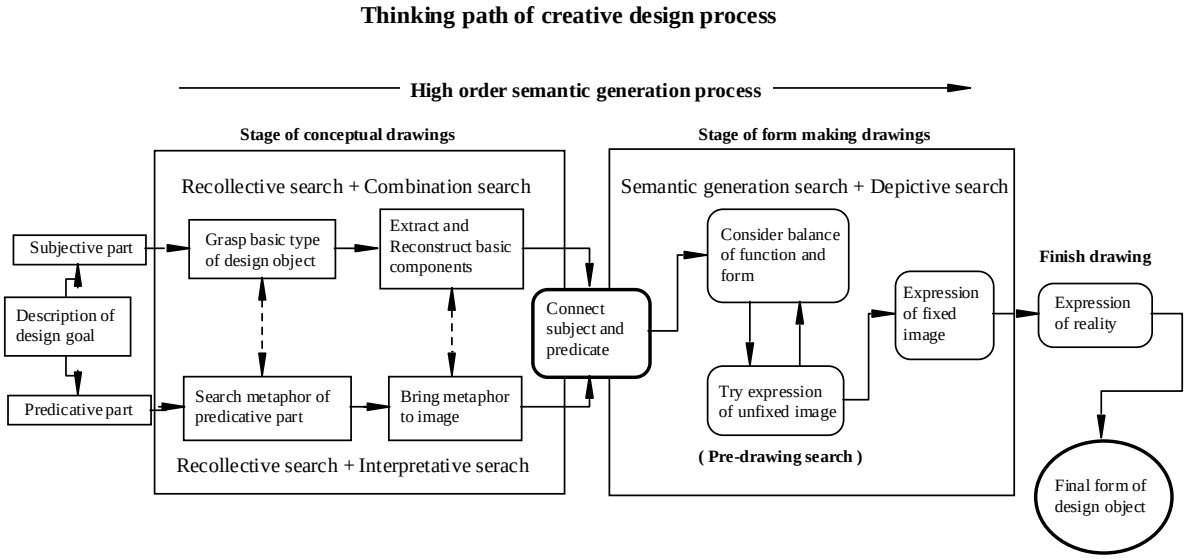


**Figure 2. Thinking path model of creative design process**

## 5. Conclusion and perspectives

### 5.1 Creative thinking needs long searching path

From this thinking path model, we found that creative thinking needs long searching path. The reason of this is as follows.
In this experiment, the subject 4 seemed to take the most complicated thinking path and then she brought the best results of design. The times taken in the thinking process are not related to the distance of thinking path. For example, the subject 1 took long times in the stage of search of semantic generation, but his thinking path was not so complicated. The numbers of idea sketches do not related to the distance of thinking path. For example, the subject 3 generated the largest numbers of sketches, but her thinking path was simple. In case of the subject 2, she took many times in the stage of interpreting search, but her thinking path was also simple and the result was not so good in balance of function and form.
The distance of thinking path is related to the times of changing search modes and the numbers of searching modes used in the thinking process. We concluded that the designers made efforts to take as many searching modes as he/she could for getting creative thinking. The creative result cannot be got without taking effort to search the best clue of creation. In creative thinking process, designer must take at least 3 stages of searching modes: interpretative search, semantic generation search and depictive search. The best result can be got when the designer take adequate searching modes in adequate times of dynamic situations of thinking process.

After this experiment and analysis, many things are left for future researches. The most important thing is the method of analysis. To make more objectify the dwell-in observation, we should have a systematic description tool of nonverbal behaviors in creative thinking process. To confirm the relations between searching modes and creativity, we might need much more experiments. To clarify the inner process of pre-drawing, several results of recent brain science might be significant. Even if all things mentioned above might be done nicely, still the approach to clarify the mechanisms of human creative thinking would need long way.

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