CONSIDERATION OF ROLE OF SKETCHING BASED ON THE MULTISPACE DESIGN MODEL

Research on the Role and Effects of Display Skills in Design Idea Generation (5)

Yuuichi IZU*, Koichiro SATO**, Takeo KATO**, Yoshiyuki MATSUOKA**

* Shizuoka University of Art and Culture Chuo 2-1-1, Naka-ku, Hamamatsu 430-8533, Japan
** Keio University Hiyoshi 3-14-1, Kohoku-ku, Yokohama 223-8522, Japan

Abstract: In product design, sketching while designing serves various roles, but the effects of individual sketching skills, such as perspective expression, structure, and shape development, have yet to be clarified. Herein a structural model of sketching skills is proposed to unify and classify sketching skills, and the role of sketching in the thinking process of design is analyzed using the Multispace Design Model as a comprehensive viewpoint based on the effects of various sketching skills previously elucidated. The results show that in the thinking process of design, sketching is used to generate ideas for the optimum design by a top-down process, which optimizes the results in physical space using the analysis results in psychological space. Additionally, sketching is used to evaluate ideas for the emergent design by a bottom-up process, which extract new meanings in psychological space based on attribute development in physical space.

Keywords: Structural Model of Sketching Skills, Thinking Process of Design, Multispace Design Model

1. Introduction

In product design, sketching while designing serves various roles, but the effects of individual sketching skills, such as perspective expression, structure, and shape development, have yet to be clarified. Herein a structural model of sketching skills is proposed to unify and classify sketching skills, and the role of sketching in the thinking process of design is analyzed using the Multispace Design Model as a comprehensive viewpoint based on the effects of various sketching skills previously elucidated. The results show that in the thinking process of design, sketching is used to generate ideas for the optimum design by a top-down process, which optimizes the results in physical space using the analysis results in psychological space. Additionally, sketching is used to evaluate ideas for the emergent design by a bottom-up process, which extract new meanings in psychological space based on attribute development in physical space.

In the first paper [3], sketching skills were extracted and divided into classes according to the differences in the acquisition level. As a result, “the structural model of sketching skills” (hereinafter called the Structural Model) was proposed to show the relationship between sketching skills.

The second paper [4], which applied the Structural Model to analyze a designer’s sketching skills, demonstrated the effectiveness of the model in designers’ sketches by analyzing sketches prepared by designers.

The third paper [5] applied the Structural Model to analyze the influence of sketching skills on rough sketching and idea sketching. The analysis revealed that sketching skills are related to feature representations of shape in rough sketching and the exact expression of shape in idea sketching.

In the fourth paper [6], the Structural Model was applied to analyze the relationship between sketching skills.
and extraction of keywords because keywords are often used in conjunction with sketching. Sketching skills that develop shape details and constituent elements influence keywords extraction.

The aim of this study is to clarify the role of sketching in the thinking process on product design. The aforementioned effects of sketching skills are applied to the Multispace Design Model as a comprehensive viewpoint to evaluate the thinking process using sketches in product design.

This paper is organized as follows. Chapter 2 describes the proposed Structural Model in our previous studies and the effects on different sketching skills (e.g., purpose of the sketch and keywords extraction). Chapter 3 discusses the role of sketching skills in the design thinking process by applying the aforementioned effects of sketching skills to the Multispace Design Model. Chapter 4 discusses the role of sketching from the viewpoints of means-ends analysis and optimum-emergent design, while Chapter 5 provides conclusions and the future research direction.

2. Structural Model and the effects of sketching skills

2.1. Structural Model

Figure 1 shows the Structural Model, which was proposed using analysis to extract sketching skills based on data of students’ sketching education. Sketching skills are classified and structured using ISM (Integrated Structural Modeling), quantification (type III), and cluster analysis [3].

In the Structural Model, sketching skills are divided into four expression skills and four development skills, which enable accurate expressions of design solution candidates (hereinafter called design ideas) and realize concrete ideas, respectively.

“Skills for expression of three-dimensional form” are based on understanding the form, while “skills for expression of perspective” are based on understanding of the perspective and shade. “Skills for the expression of curved form” are based on expression of the surface and ridgeline. “Skills for the expression of the object image” are based on freehand drawing skills. “Skills for development of structure” realize variations of basic structures and forms. These basic structures and forms are used in “skills for development of shape”. “Skills for development of detailed shape” are used to realize detailed elements, which are then used in “skills for development of constituent elements” that serve as distinctive features of the object.

Each sketching skill is classified into three groups: “development of structure”, “development of shape”, and “development of element” from its relationships. The arrows in Figure 1 express the precondition of acquisition and often indicate that sketching skills are necessary.

2.2. Multispace Design Model

The Multispace Design Model (Figure 2) [7-9] enables design activities and design knowledge to be modeled in multiple spaces. Design activity is expressed in thinking space, while design knowledge is expressed in knowledge space. Knowledge space is divided into subjective and objective knowledge. Thinking space is divided into mental and physical spaces. Mental space describes mental design elements and their relationships. It can be subdivided into value and meaning spaces, and physical spaces. On the other hand, physical space specifies physical design elements and their relationships, and can be subdivided into state and attribute spaces.

Value space consists of design elements expressing diverse values, including social values, cultural values, and individual values. Meaning space is comprised of design elements required to express values, such as functionality and image. State space contains design elements necessary to manifest meaning, such as movement or shadow. These elements depend on the circumstance, such as a human and the environment. Attribute space is composed of artificial elements, such as shape, color, and material required to realize a state. Similarly, knowledge space here can be divided into general objective knowledge and subjective knowledge.
2.3. Purpose of sketching and the effects of sketching skills

It has been hypothesized that the skills required for rough sketching to create images and those in idea sketching to derive structure, shape, and specifications differ. Our previous study evaluated rough sketches and idea sketches drawn by ten students learning design and six designers working in electronics manufacturing using a structural model [5]. The results were assessed using discriminant analysis. The findings are summarized as follows:

(1) Rough sketching: Skills for the expression of the object image and skills for expression of three-dimensional form as well as skills for development of constituent elements strongly influence rough sketching.

(2) Idea sketching: Skills for expression of perspective and skills for expression of curved form as well as skills for development of constituent elements and skills for development of detailed shape strongly influence idea sketching.

2.4. Effects of sketching skills on keywords extraction

Because sketching and keywords are often used together, it has been speculated that elucidating their relationship should improve the thinking process of design. Our previous study analyzed the results of keyword extraction and sketch drawing by 30 students who were learning design using the Structural Model and the Multispace Design Model [6]. The following relationship are confirmed:

(1) Relation 1: Many keywords are extracted in relation to the meaning of an image or a function. Skills to develop structure the drawing of sketches from keywords.

(2) Relation 2: Skills for development of shape create shape from structure. Skills to develop constituent elements and detailed shape create elements from shape. These skills affect the extraction of keywords, which represent the state or attribute.

(3) Relation 3: Skills to develop constituent elements and detailed shape influence keyword extraction by expressing new meaning when repeatedly developing the detailed shape and elements.

3. Sketching skills in design process

3.1. Design Thinking Model and sketching skills

In the Design Thinking Model of Matsuoka [7, 10] (Figure 3, right), the thinking process of design in the Multispace Design Model (Figure 3, left) can be divided into three categories: analysis (design problem analysis), generation (idea generation), and evaluation (idea evaluation). The thinking process of design using a sketch can be described as follows by applying the effect of each sketching skill shown in the previous chapter to these three classifications [10].

(1) Analysis clarifies the relationships among various elements related to the design problem and leads to general rules that provide context to the design problem.

(2) Generation leads to design ideas as potential solutions to the design problem.

(3) Evaluation clarifies the position of the various elements related to the design problem according to general rules.

Assuming that sketching skills affect both rough and idea sketches and the relationships elucidated in the previous chapter apply, then sketching skills in the design thinking process can be summarized as follows:

(1) Analysis clarifies the relationships among the various elements related to the design problem in response to keyword extraction where keywords represent the meaning of an image and functions. Analysis requires sketching skills to develop the basic structure, shape variations, detailed shape, and constituent elements.

(2) Generation leads to design ideas as potential solutions to the design problem expressed by the sketches. Required rough sketching skills include those to express the object image, three-dimensional form, and to develop constituent elements. Necessary skills for idea sketching include those to express perspective, express curved form, develop constituent elements, and develop detailed shape.

(3) Evaluation clarifies the position of the various elements...
3.2. Sketches in analysis, generation, and evaluation

Figures 4–6 show examples of extracted keywords and sketches from previous research, where the arrows denote the order of keyword extraction and sketch expression.

Figure 4 shows rough sketches [5] used to analyze the influence of sketching skills on rough sketching and idea sketching (Section 2.3). "Triangle" and "Egg", which represent the images, are extracted as keywords and generate three different design proposals for a steam iron. These design proposals consist of different structures, forms, and elements. Table 1 shows the evaluation results using the structural model of the rough sketches drawn in five minutes for a steam iron and the idea sketches drawn in 60 minutes for a liquid crystal projector by 16 subjects. Comparing the number of deployed structures and the number of deployed shapes between rough sketching and idea sketching shows that typically idea sketching develops two or more shapes from one structure, while rough sketching develops one shape per structure.

A test of the average difference (t-test) was performed on the number of structures and shapes in the rough and idea sketches shown in Table 1. Although the number of developments of structure and shape does not differ significantly in rough sketching, the number of developments does differ in idea sketching (P<0.05). As mentioned above, the rough sketches shown in Figure 4 can be considered as a single analysis to clarify the relationship between elements, which is conducted by developing a different structure, shape, and elements.

Figures 5 and 6 show examples of idea sketches [6] that analyze the relationship between sketching skills and keyword extraction (Section 2.4). Table 2 shows the evaluation results using the Structural Model of the sketches drawn after the keyword extraction (hereinafter called K→S) and the sketches drawn in parallel with the keyword extraction (hereinafter called K↔S) by ten subjects for three different design themes. Although the number of extracted keywords is smaller for K↔S compared to that for K→S, many sketches are deployed. In particular, many shapes and elements are conceived.

Figure 5 shows examples of idea sketches drawn by K→S. Two design ideas for a stapler (Figure 5, left and center) are developed from the same structure while extracting "easy-to-grip" and "curved-surface shape" to represent meaning. Next, "grooves corresponding to the finger" represents an extracted attribute by expressing the detailed shape and elements (Figure 5, right). Thus, generation leads to design ideas as potential solutions as
two or more shapes and elements are realized from the same form. Moreover, it is shown that the idea sketches affect the extraction of keywords expressing attributes.

Figure 6 show the examples of idea sketches drawn by K⇔S. In the design of a desk light, the sketches are initially modified by extracting “flexible” and “point light”, denoting a state or attribute from the "metal plate", which is the meaning in the design of desk light. Furthermore, as a result of drawing a detailed element using skills to develop constituent elements and detailed shape (two center images in Figure 6), “snake” is extracted (right image in Figure 6) as a new meaning. It is possible that the three sketches on the right-hand side of Figure 6 are design proposals in which only the detailed shape differs but the general form and shape are similar (hereinafter called the same concept proposal).

Table 3 shows the average number of the same concept proposals observed in K→S and K⇔S by 30 subjects [6].
4. Role of sketching in design process

4.1. Means-ends analysis and sketching

Means-ends analysis is a process to solve problems in order to reach a final target. Here it is used to evaluate the thinking process of design using sketches. In means-ends analysis if a step is assembled to a target and is followed by another one, the method to reach a target is called an algorithm. On the other hand, a method that has the potential to solve the problem effectively by relying on experience and intuition is called heuristic [11].

The rough sketches in Figure 4 after keyword extraction show a procedure that initially develops the structure followed by form features, while the idea sketches in Figure 5 show a procedure to extract keywords representing attributes by initially developing the structure followed by shape and elements. In these procedures, after developing the shape from structure and elements from shape, the design is evaluated by referring to the analysis result. If the design problem is judged to be unsolvable, the procedure returns to the structure and begins again. As previously mentioned, the design is developed mainly based on an algorithm where a design idea is realized by repeatedly deriving the structure, shape, and elements to express the analysis results (Figure 7, left).

In contrast, the idea sketches in Figure 6 are used to extract keywords representing new meaning by repeating the evaluation and modification of features and elements of the detailed shape and elements. Although the basic structures and shapes of each sketch in Figure 6 are more common (same concept proposal), there is little relevance between the extracted keywords and the correspondence to each sketch, implying that keywords are extracted by looking at the sketches and not from the analysis results. Hence, this procedure can be considered based on heuristics, and may solve a problem effectively by relying on experience and intuition, as shown by the dotted line in Figure 7, right.

It is possible that there are two types of thinking processes using sketches. One employs an algorithm to arrive at the final design idea by repeating development of structure, shape, and elements. The other focuses on heuristics to extract new meaning by relying on experience and intuition to repeat development of detailed shapes and elements.

4.2. Optimum-emergent design and sketching

Design Science aims to clarify and systematize various knowledge of design, and emergence has attracted attention as a concept to explain the process of new design solution [7, 12].

In emergence a local interaction generates an overall order relation, producing a new function. Two processes are involved: a bottom-up and top-down. In a bottom-up process, order on the whole is revealed by elements and their interactions. In a top-down process, order on the whole governs the action of elements. In the design methodology to deal with various design methods systematically, emergent design is a method focusing mainly on a bottom-up viewpoint where the design artifacts have the characteristics of emergence (Figure 8, right). On the other hand, optimum design is a method focusing mainly on a top-down viewpoint where the design proposal is derived near the optimal value using a clear evaluation index based on reductionism (Figure 8, left).

The rough sketches in Figure 4 are mainly drawn by a
top-down process based on the extracted meaning. The idea sketches in Figure 5 extract attributes by evaluating the detailed shape and elements in the sketches based on the meaning extracted by the analysis result. This process can be considered as a procedure that focuses on optimal design by a top-down process (Figure 8, left).

By contrast, in the idea sketches in Figure 6, detailed shape and elements are initially drawn based on the meaning extracted by the analysis result. By repeating the correction of the detailed shape and elements, keywords representing the new meaning are extracted. This process can be considered as a procedure that focuses on emergent design by a bottom-up process (Figure 8, right).

When the optimum and emergent design processes are applied to the Multispace Design Model, the thinking process of design with sketching can be described as follows. The rough sketches in Figure 4 extract meanings by repetition of sketching development. This process focuses on optimum design by a top-down approach (Figure 9, rough sketch).

Similarly, the idea sketches in Figure 5 extract meanings while analyzing the design problems in psychological space. Then keywords representing the attribute are extracted by expressing the structure, shape, and elements based on the extracted meaning. This process focuses on optimum design by a top-down approach (Figure 9, Idea sketch 1).

By contrast, the idea sketches in Figure 6, which show the initial structure, shape, and elements, are expressed by a top-down process based on the meaning. Next, an evaluation is conducted while repeatedly developing the details of the shape and elements to extract new meanings. This process focuses on emergent design by a bottom-up approach (Figure 9, Idea sketch 2).

4.3. Role of sketching in product design

Here the effects of sketching mentioned in Chapter 1 are considered based on the results of the previous section. “Externalizing and analyzing thoughts and simplifying multi-faced problems to make them more understandable”
[1] indicates that the extraction of an attribute, which serves as a design solution candidate, becomes easier by externalizing the multi-faceted design problem using sketching. This process is a type of optimum design (Figure 8, left, Figure 9, Idea Sketch 1).

“The motion of the hand is completely uncontrolled with the head, and while drawing many sketches, a line can be drawn by chance, inspiring a new design” [2] implies that the feature of the shape is expressed by coincidence while drawing sketches influences the extraction of new meanings, which affect analysis results. This process is a type of emergent design (Figure 8, right; Figure 9, Idea Sketch 2).

5. Conclusion

This study analyzes the previously elucidated effects of sketching skills based on the viewpoint of the Multispace Design Model and considers the role of sketching in the thinking process on product design. The following roles of sketching are suggested in the thinking process of design. One is that sketching focuses on optimum design by a top-down approach, which optimizes the analysis results in psychological space for physical space. The other is that sketching focuses on an emergent design by a bottom-up approach, which extracts new values and meanings in psychological space based on the development of the attributes in physical space.

As the next step, we plan to elucidate the role of various other display skills utilized in design by performing a similar analysis.

Acknowledgements

This work was supported by the Japan Society for the Promotion of Science, Grant-in-Aid for Scientific Research (C) (15K00692).

References


