SHAPE COGNITION IN DESIGN

Constructing a Cognitive Model of Shapes for Different Design Fields

CHENG-JUI WANG
Institute of Applied Arts, Group of Architectural Design,
National Chiao Tung University, Hsinchu, Taiwan 30050

Abstract. The purpose of this paper is to reveal the characteristics of shape cognition of different design fields in the 'intuitive design' domain, and to construct a cognitive model of shape cognition for different design fields. The research procedure used in this study consisted of two phases. The first phase was applied to protocol analysis study of three professional designers in architectural design, industrial design and graphic design respectively. In the second phase, one controlled laboratory experiment was designed to reveal the characteristics of designers' shape perception in different 'intuitive design' fields. By these empirical findings, we found that designer's cognitive processes of shapes would be not alike in different design fields. The results suggest that in different design fields, designer's shape cognition processes will be different, and in each design field, similar cognitive processes of shape contained different design meanings.

1. Introduction: Problems of shape cognition in design

Although studies on design thinking is becoming a serious and important area of design research, there is still lack of theoretical approaches that directly address its domain-specific characteristics for a long time. Scholars in design theory recently have moved their attention to some domain-specific topics. Several studies have found that the way designer process information will be different in different design domain. The studies of design reasoning found that the reasoning process will be not alike in different design domain (Lloyd, 1994). More recently, as a study on shape perception in design found that practicing experiences will affect designers' shape perception behaviour (Liu, 1995). All these studies illustrated that there existed some domain-specific characteristics in design behaviour. But until now, designers' cognition process still be treated as the same in the so-called "intuitive-design" domain (Akin, 1984).

On the other hand of theoretical approach, the shape perception study has grown its importance in design researches. The design drawing itself had been explored as an indispensable part of the design process and the underlying

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design thinking (Herbert, 1993; Goldschmidt, 1994). Both design knowledge and design concepts draw extensively upon the representation of shapes. Moreover, several studies also found that designers' shape processing process will be affected by their practicing experience (Schön, 1992; Lloyd, 1994; Liu, 1995).

As William Mitchell suggested that architectural designers' shape cognition process will be affected by these shapes' design meanings (Mitchell, 1992). The purpose of the current paper is to reveal the characteristics of designers' shape perception, and to construct a primary shape cognition model for designers from different 'intuitive design' fields.

2. Protocol analysis: shape processing modules in design

Base on past researches, we make an assumption that in different design fields designers' shape cognition pattern will be not the same, and even similar shape cognition process contain different design meanings. The research hypothesis were first test by protocol analysis, we want to use protocol analysis to explore the shape processing process in design. Protocol analysis is a technique devised to infer the information processing mechanism underlying human problem solving behaviour (Ericsson and Simon, 1993).

Three experienced designers (one architectural designer, one industrial designer and one graphic designer which all have more than five year practicing experience) were selected as our subjects. These three subjects were given their own design field related design problems (for example, the architectural designer was asked to design a civil culture center) under laboratory conditions. These design problems were all selected from a entrance examination of a graduated design school, and have the same level of difficulties. These subjects' design processes in their entirety were recorded on videotapes. The audio part of these tapes were transcribed and used in the analysis in conjunction with the sketches and notes of designers. Here are samples of these subjects' sketches and the related shape perception behaviour analysis (Figure 1).

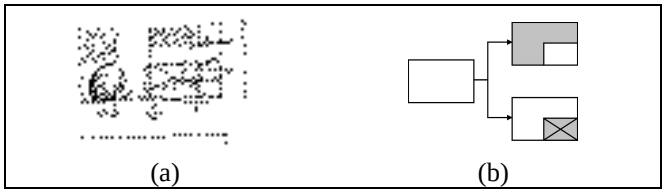

Figure 1. (a) The drawing of subject 1 (architectural designer) and (b) Subject 1's shape perception behaviour analysis

In figure 1 we can see that subject 1 (architectural designer) first draw a large rectangle to represent the initial site, and then he draw another rectangle to represent an open space on the bottom-right corner of this site. This shape exploring process illustrated that subject 1 was trying to explore subshapes within the primary shapes (Figure 1-b).

By analysis these three subjects' protocol data, we found some shape processing modules were frequently used in theses three subjects' design processes, and designers from different design backgrounds employed these similar rules of shape processing in their design process. These designers' shape processing modules were concluded as 6 major modules. The definitions of these major shape processing modules were listed in Table 1.

TABLE 1. Six major shape processing modules in design

Individual subshapes	In search for subshapes contain individual, enclosed existing shape from primary stimulus.
Holistic subshapes	Subshapes that include the whole existing shapes.
Inbetween-shape subshapes	In search for subshapes that between two or more individual existing shape.
Within-shape subshapes	These subshapes are based on the original factor of these existing shapes, and are included in the contour of original single existing shape.
Outer-shape subshapes	In search for subshapes whose original form factors are based on existed shapes but not belong to the original shapes.
Volumetric-shape subshapes	The subshapes are transformed from original two-dimensional shapes and have three-dimensional properties.

The results suggest that designers from different fields would use some similar shape processing method in the design process. In conclusion, designers from different 'intuitive-design' fields share some common shapes processing behaviour, and these behaviour are domain-general in the 'intuitive-design' domain.

3. Empirical study: preferred shape perception in different design fields

Although the previous study suggests that designers' shape processing process consist some domain general behaviour, but from these protocol data, we also found some domain-specific tendencies on shape perception. According to

Reed, a designer naturally structures a primary shape based on interpreting the shape and then recognizing its emergent subshapes (Reed, 1974). William Mitchell also point out that architectural designers' shape cognition process will be affected by these shapes' design meanings (Mitchell, 1990; 1992). By these point of views, we make the second hypothesis that the different design backgrounds of designers and the specific design meanings of shapes would affect designers' shape perception tendency. This hypothesis was further test by a controlled laboratory experiment.

The major objective of this experiment is to compare the type of subshapes emergent from a primary shape by designers from different 'intuitive design' fields. Twelve design majored graduated school students were chosen as our subjects (there are 4 students major in architectural design, 4 students major in industrial design and the other 4 students major in graphic design), and were classified as three groups based on their different design backgrounds. These subjects were asked to draw as many as the subshapes that emerged from the 5 primary shapes (Table 2). Before the formal test, a 'warm-up' test exercise was given to ensure that subjects completely understood the task.

TABLE 2. Subshapes emergent tendency of 3 groups of subjects

Primary test stimulus	subjects*	Subjects' shape perception modules					
		individual subshapes	Holistic subshapes	Inbetween-shape subshapes	within shape subshapes	Outer-shape subshapes	volumetric-shape subshapes
							
	Group 1	8.50%	3.20%	54.30%	12.80%	21.30%	----
	Group 2	8.73%	3.95%	21.28%	29.67%	36.38%	----
	Group 3	9.18%	1.12%	12.18%	40.10%	37.42%	----
	Group 1	6.27%	1.95%	42.65%	10.32%	38.80%	----
	Group 2	10.23%	5.43%	51.30%	5.22%	27.82%	----
	Group 3	9.05%	5.20%	33.88%	20.02%	31.85%	----
	Group 1	1.67%	----	----	63.84%	28.91%	5.58%
	Group 2	4.82%	----	----	39.88%	33.90%	21.40%
	Group 3	6.17%	----	----	70.09%	15.16%	8.75%
	Group 1	31.28%	0.88%	7.78%	7.35%	52.72%	----
	Group 2	36.80%	1.70%	5.05%	16.23%	40.22%	----
	Group 3	42.50%	7.05%	10.15%	15.38%	24.92%	----
	Group 1	7.25%	0.88%	42.05%	6.04%	43.43%	----
	Group 2	7.17%	5.03%	21.83%	19.05%	46.47%	----
	Group 3	7.35%	4.85%	16.60%	34.50%	36.70%	----

*Group 1 are architectural design background subjects, group 2 are industrial design background subjects and group 3 are graphic design background subjects.

The results of this experiment were shown in Table 2. Table 2 show the average subshapes emergent tendency in 5 primary shapes of three groups of

subjects. We use the 6 primary shapes processing modules found in the previous protocol analysis to analyze these subjects' emergent subshapes. Analysis of the data suggests some interesting phenomena of these 3 groups of subjects:

3.1. SHAPE PERCEPTION TENDENCIES OF ARCHITECTURAL DESIGN GROUP:

Compare to the other two groups of subjects, we found that architectural design background subjects seem tend to focus their attention on 'inbetween-shape subshapes' and 'outer-shape subshapes' perception in the test for stimulus 1, 2 and 5. From the results in the test for stimulus 4, we found that architectural design group especially tend to search for 'outer-shape subshapes' when the primary shape is only one individual shape. This phenomenon is unique from the other two groups.

In the results of shape perception on stimulus 3, the data suggests that architectural design group is surprisingly lack of finding 'volumetric subshapes'. This doesn't mean that architectural designers are all lack of 'volumetric subshapes' perception. Because the 'volumetric subshapes' perception used in this experiment is based on shape transformation, but not real three-dimensional shape perception. The rational explanation of this phenomenon is that architectural design group didn't focus their attention on discovering shape in an individual shape.

By these findings, we can conclude that the major shape perception and processing modules of architectural designers are 'inbetween-shape subshapes' and 'outer-shape subshapes'.

3.2. SHAPE PERCEPTION TENDENCIES OF INDUSTRIAL DESIGN GROUP:

In the results of experiments on stimulus 1 and 5, industrial design group seem tends to use 'inbetween-shape subshapes', 'within-shape subshapes' and 'outer-shape subshapes' shapes perception modules with equal tendency. Beside in the test results of stimulus 2, industrial design group tends to focus their attention on 'inbetween-shape subshapes' rather than on 'within-shape subshapes' or 'outer-shape subshapes' cognition. This illustrate that industrial design group will apply different shape processing modules to shapes that contain only one primary shape from those shapes contain two or more primary shapes (e.g., as stimulus 2 contain just one kind of shape—rectangle, stimulus 1 contain triangle, circle and rectangle shapes.).

In their perception of stimulus 3, we found this group of subjects use 'volumetric subshapes' perception module more frequently than the other two groups of subjects. This means that industrial design group express highly dimensional transformation tendency on shape perception.

3.3. SHAPE PERCEPTION TENDENCIES OF GRAPHIC DESIGN GROUP:

By the results from test on stimulus 3 and 4, graphic design group seem tend to search for ‘with-shape subshapes’ rather than ‘outer-shape subshapes’ in an individual primary shape. In the perception of filled primary shapes like stimulus 2 and 5, graphic design group will focus their attention on ‘within-shape subshapes’ and ‘outer-shape subshapes’ perception. All these results suggest that the ‘inner-shape subshapes’ perception module is the major shape perception module of graphic design background subjects.

4.Conclution

The experimental results of designers’ shape perception tendency in different ‘intuitive design’ fields can concluded as below:

a) Architectural designers tend to perceive ‘inbetween-shape subshapes’ and ‘outer-shape subshapes’.
b) Industrial designers have equally tendency on perceiving ‘inbetween-shape subshapes’, ‘within-shape subshapes’ and ‘outer-shape subshapes’.
c) Graphic designers seem focus their attentions on ‘within-shape subshapes’ perception.

By these findings, it is obviously that the shape perception modules used by these three groups of designers have close relationship with their own design profession and design education. Based on past human cognition research, Irvin Rock in his book--*The Logic of Perception* build a fundamental theory about human perception. He divides human perception process into three phases—proximal stimulation, literal perception and preferred perception. Figure 3 is the framework of Rock’s theory.

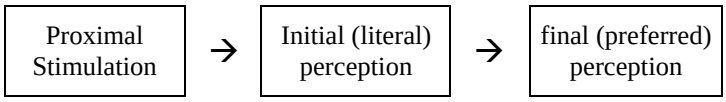

Figure 4 The human perception framework (after Rock, 1983)

Based on the empirical findings described above, Irvin Rock’s human perception framework can be modified into the shape cognition in design framework shown in figure 4.

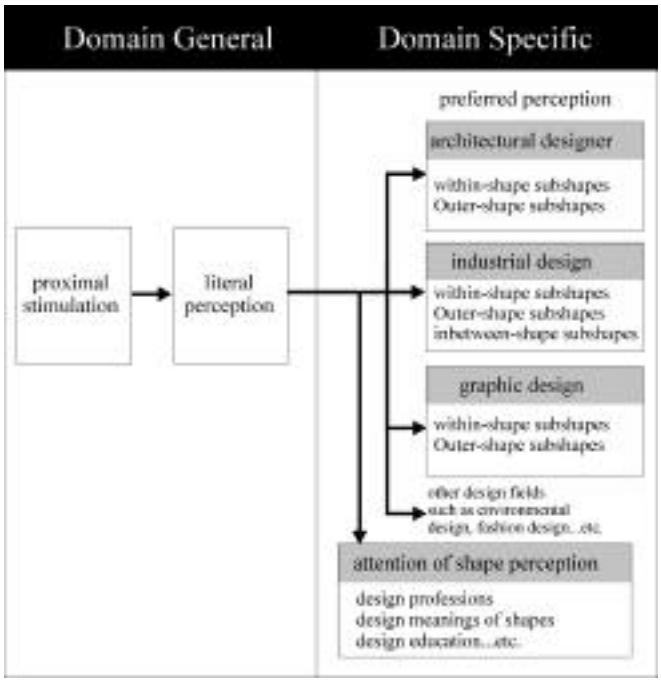

Figure 4 Shape cognition framework in design

The framework here suggest that in different design fields of 'intuitive design' domain, designer's shape perception processes will be different. Among these specific design fields, similar perception processes of shape contained different design meanings. This supports the conclusion that these various cognitive characteristics of shapes are due to some specific design meanings and design traditions in each design field.

References

Akin, Ö.: 1984, An exploration of design process, in N. Gross (eds.), *Development in design methodologies*, 189-208, John Wiley & Son, New York

Ericsson, K. A. & Simon, H. A.: 1993, *Protocol analysis-verbal report as data*, revised ed., MIT Press, Cambridge, MA.

Goldschmidt, G.: 1994, Gestalt factors and repetition, *in* W. D. Ellis (eds.), *A Source book of gestalt psychology*, Kean Paul, London

Herbert, D.: 1993, *Architectural study drawings*, Van Nostrand Reinhold, New York

Liu, Y. T.: 1995, Some phenomena of seeing shapes in design, *Design Studies* 16(3), 367-385

Lloyd, P.: 1994, Is there a case for generic design, *Language of design* No. 2, 243-262

Mitchell, W. J.: 1990, *The logic of architecture*, MIT Press, Cambridge, MA.

Mitchell, W. J.: 1992, The use of inconsistency in design, in Y. E. Kalay (eds.), *Principles of computer-aided design: evaluating and predicting design performance*, John Wiley & Sons, New York

Reed, S. K.: 1974 Structural description and the limitations of visual imagery, Memory and Cognition vol. 2, 329-336

Rock, I.: 1983, *The logic of perception*, MIT Press, Cambridge, MA.

Schön, D. A. & Wiggis, G.: 1992, Kinds of seeing and their function in design, *Design Studies* 13(2), 135-156