SOME PHENOMENA OF ANALOGICAL THINKING IN DESIGN

Conventional Media vs. Computer Media

YUAN-YU LIAO
Graduate Institute of Architecture
National Chiao Tung University
HSINCHU, 30050, TAIWAN
kristy@arch.nctu.edu.tw

Abstract. Analogy has been ascribed a key role in architectural design. Until now, there has been no complete theory describing how the analogical thinking process works in the design domain. Analogical thinking usually relates to freehand sketches and rarely connects to computer media. This research attempts to investigate analogical thinking from the perspective of the conventional media and computer media. Four analogical thinking in design phenomena have been established.

Keywords. Analogical thinking; sketching; computer media; cognitive experiment.

1. Introduction

Analogy is important in human cognition because it is the main life-long human cognition affecting human learning, thinking, working, and creativity. Psychological studies reveal that perceiving the lack of something£-whether physical, emotional, spiritual, or intellectual£-inspires us to search for an approximate resemblance to fill its place (Stafford, 2001). The cognitive activity of analogy is a process to simulate the perceived real substance and retrieve analogical ideas from the real world while elaborating a mental analogy (Morin, 1986). It is also particularly useful for solving an unfamiliar new problem without adequate or directly applicable knowledge.

Throughout the design fields, analogy has been ascribed a key role (Laseau, 2001; Leclercq, 2002). The design literature uses the term "analogy" very loosely, as we use it in everyday life, where it often denotes similarity or

resemblance in a general sense. Schön and Wiggins (1992), also, pointed out how powerful the transfer of concepts from one case to the next and from one field to another can be. Ideas arrive from various origins, and therefore designers do not be restricted by the single domain which they work and can obtain design ideas from other fields (Do & Gross, 1995). Natural forms and biological developments provide a possible source of inspiration for diverse ideas during the design development stage (Gero, 1991). For example, Tzonis (1992) indicates that the form of Unite Habitation, designed by Le Corbusier, is associated with several images, including a ship, a wine rack, a primitive hut, and a Greek temple.

2. Problem Statement

Studies of design process often identify analogy as important activities in creative designing. However, there is no comprehensive theory that describes how the analogical thinking process works in the design field. When researchers discuss this issue, they usually cite theories from other areas.

Moreover, when researchers explore designers' analogical thinking, they usually focus on sketching and rarely discuss the possibilities of computers. Generally, analogical thinking happens at the conceptual design stage, which in the traditional view includes sketching. Sketching gives rise to interactive imagery and enhances analogical reasoning (Verstijnen and Heylighenetal, 2001). Architects use a pencil to develop their ideas. The lines they draw are obscure but lead to the possibilities of analogy. However, the appearance of the computer has created a new era for modern society (Mitchell, 1998; Liu, 1996). It has already been proved that the conceptual design process could happen only with the computer media (Hanna & Barber, 2001). The computer media provides a greater variety of essentials than conventional media, such as continuousness, continuous pliability, localized focus, and fluidity, and, it is biomorphic, it is quintessentially an analogue (Porada, 1999).

If researchers are to develop efficient design tools for architects, we must know more about analogy in architectural design rather than presume that the tools used in the design process are unchangeable. This research, therefore, attempts to investigate analogical thinking from the perspective of the conventional media and computer media. The main goal of this study is to provide cognitive experiment evidence regarding some phenomena of analogical thinking in design. This study also aims to discover the relationship between analogical thinking and media.

3. Methodology and Steps

3.1. EMPIRICAL STUDY

An experiment was conducted to better understand analogy in the design domain. This experiment was a design assignment of short duration where the subjects had to finish their conceptual designs within the allotted time. However, the source and target (Genter, 1983) are not the main goals of this research. In order to achieve the experiment's purpose in the given amount of time, the design ideas and the design purpose are bounded by a particular resource and one topic. The organic analogy is one of the most widely discussed issues in the design domain (Couceiro, 2005; Do & Cross, 1995), so two organisms were selected that the subjects maybe knew something about but were not familiar with. The experiment was held in two phases with an interval of one month between them. Six expert designers with more than five years of design-based education were chosen to participate in the experiment. All were proficient in conventional media and computers.

In phase one, the subjects were asked to express their concepts using conventional media, which the subjects used habitually. The topic was a transient living space inspired by the sponge. The whole process took about one hour. Before the beginning of every design assignment, the six subjects were asked to read the related materials to enhance their background knowledge and then think for ten minutes. Then, the subjects were given forty minutes to create their designs. Following this phase, the author asked the subjects to describe their design process and answer some questions. The entire process was recorded by video and audio tapes.

In phase two, the author wanted to understand the same thing as in the first experiment only this time using computers. The objective was to learn how the analogical thinking process functioned when using a novel medium. The design topic used for this phase was the new type of roadside stalls we have in Taiwan inspired by the jellyfish. This all took about one hour and twenty minutes. The time the subjects took to generate their designs was one hour. The other stages were the same as phase one. Interestingly, only some of the subjects could cope with phase two. Even though all the subjects had professional design experience, it does not mean that all of them could design using analogical thinking. To make sure that the experiment results were worthwhile, the author measured the experiment results based on the basic analogy theories of Novick (1988) and Genter (1983). If any of the subjects' designs did not correspond to either theory, they did not qualify for the next phase. Finally, three subjects from the six were chosen.

1. Analogical thinking proceeds from source to target.

2. The positive use of analogical transfer is that the features shared by the source and target are structural. In contrast, when the source and target analogy shares only objects attributes transfer, it is often negative transfer.

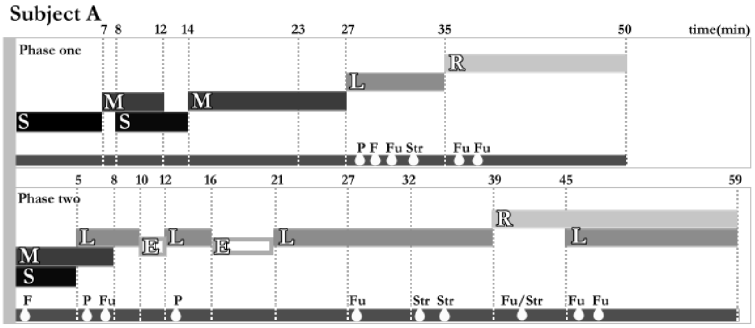
3.2. CODING SCHME

The author used a coding scheme to investigate the major visual data and minor verbal data. The coding scheme integrates two theories into one coding scheme: the five stages in analogical thinking (Holyak & Thagard, 1996); and the four types of analogies in the design field (Ricoeur, 1994).

TABLE 1. The coding scheme.

	Coding	*Definition*
Stages Holyak and Thagard (1996) and the Author's Deduction		
S	Selection	Choosing the sources to transfer
M	Mapping	Connecting the sources and target
E	Evaluation	Evaluating two or more decisions and selecting one of them
L	Learning	Confirming and sketching the final concept design
R	Representation	Describe or improve the design details
Types Ricoeur (1994) and the Author's Deduction		
P	Property	Transferring the quality or characteristic
F	From	Transferring the appearance or shape from the source
Fu	Function	Transferring the spatial function
Str	Structure	Transferring the structural relationship

Figure 1 represents all the coding results of the three subjects who managed to generate concepts using both conventional and computer media. From these figures, we can clearly see the shifting times and amounts of analogical behavior of the three subjects.



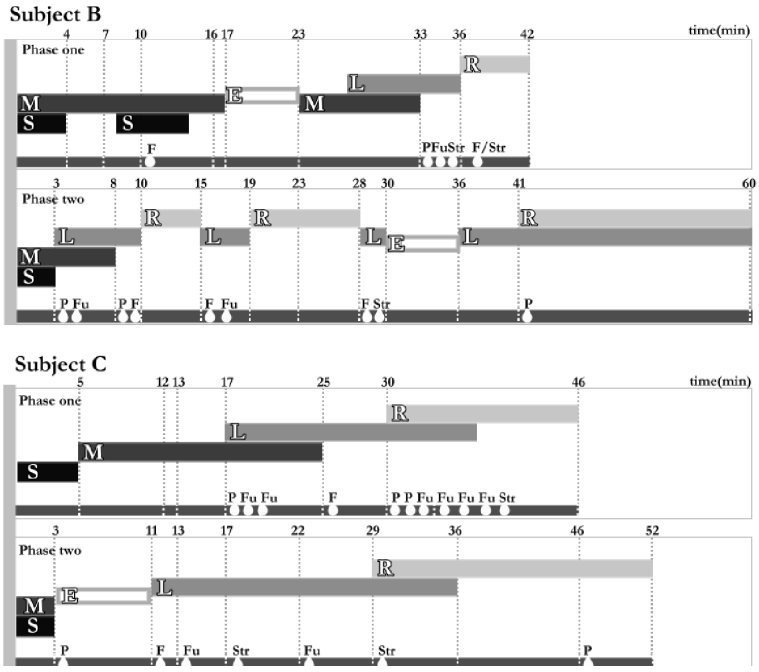


Figure 1. The coding results.

4. Analysis

Because of the coding results and the rest of the experiment data, some characteristics of analogical design thinking can be addressed.

4.1. PHENOMENON ONE

Designers search for some key words or meaningful images that contain spatial metaphors to be their analogical sources. Then, they transfer the sources to match architectural equivalents.

The crux of understanding analogical thinking is how designers choose their analogical sources and how they connect the sources with their design target. There is a general pattern pertaining to designers' analogical decision making. They search for and decide on some spatial keywords or images, such as color, light, function, structure and so on. They write down these keywords or draw some sketches inspired by them. In phase one, for example, all the subjects chose some characteristic of jellyfish that hinted at some spatial meaning, such as illuminated, umbrella structure, and flocking together. In phase two, all subjects

chose one image relating to sponge's tubular structures, because the image is like an architectural section, simple but full of spatial meaning.

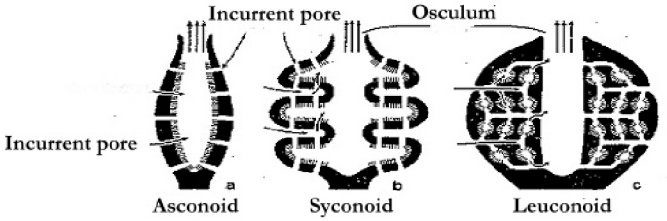


Figure 2. Three types of sponge tubular structure.

So, designers select information symbolizing spatial meaning form the source material while thinking about which images or sentences can connect to their design target. They match the source material to an architectural equivalent. Most designers choose the same sources and associate the sources with the same transfers. Table 2 shows some examples of the sources that most subjects chose and their architectural equivalents.

TABLE 2. Examples of popular sources and their equivalents.

Analogical source	*The possibilities of transfers*
The form of a jellyfish	1. The umbrella structure of traditional stalls 2. Round space
Flocking together	1. Combination 2. Group
A jellyfish's body is made up of 95% water	1. Transparency 2. Inflatable
Three layers of the jellyfish's body	Three Spatial functions
Flexible body of jellyfish	Flexible space
Zooplankton	Morphing
Sponge's tubular structures	The structure of housing
Water flow	Air current

4.2. PHENOMENON TWO

Designers transfer more functional analogies than those from other analogical types. Most designers map and create their designs with various types of analogies. The analogies of property, form, and function often appear before

those of structure since most designers consider design functions to be more important.

When we discuss the relationship between source and transfer, the types of analogical ideas must be paid attention to. The coding results show that designers select from more function and property sources among various types of spatial analogies than other kinds of analogies. The function analogy is the most important to designers. The functions contain spatial metaphors and deep relationships between sources and targets. It is not like the analogy of form, which is only attributed to mapping. Most functional analogies imply relational mapping. For example, the flexible body of the jellyfish is converted into the changeable space dimension of the roadside stall. The analogy of property also plays a key role in analogical thinking because it is the second most frequently used. Spatial properties, such as color, movement, light, composition, and so forth, are the obvious features that subjects could get from the source material.

TABLE 3. The percentages of choosing analogical types.

	Phase One(conventional media)					*Phase Two(computer)*			
	P	F	Fu	Str		P	F	Fu	Str
A	1	1	3	1		2	1	5	3
B	1	2	1	2		3	3	2	1
C	3	1	6	1		2	1	2	2
Sum	5	4	10	4		7	5	9	6
	22%	17%	43%	17%		26%	19%	33%	22%

Most designers map and create their designs with various types of analogies. According to the coding results, the types of form (F) and property (P) emerge in the early part of the process, and the type of structure (Str) appears in the latter part of the process. Most designers build their transfer with attribute mapping, such as that for form and property, and then they concern themselves with deeper analogies.

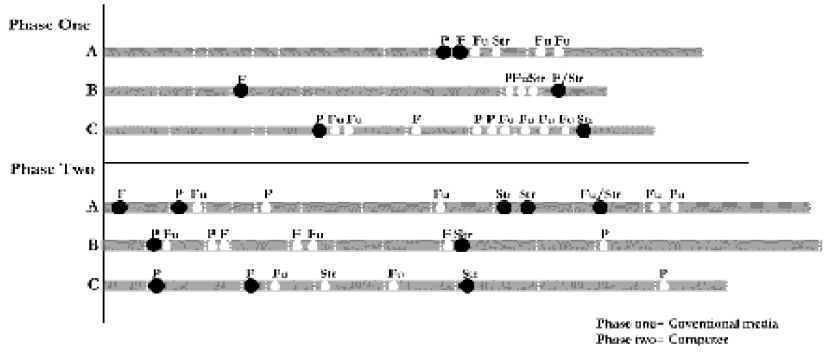


Figure 3. The order of appearance of analogical ideas.

4.3. PHENOMENON THREE

Analogical ideas are concentrated in the later part of the process when conventional media is used. However, in the computer media, analogical ideas are evenly distributed.

Figure 4 presents analogical ideas in six experiment sections. In phase one, the analogical ideas are concentrated in the later part. However, the analogical ideas are scattered in phase two, and some of them appear at the beginning of the process. In phase one, the subjects drew many diagrams at the beginning but they confirmed their design concepts during the later process. This means that analogical ideas may be in the back of their minds but not expressed until the later process. Seemingly, most analogical ideas do not happen during the early design stages but aggregate during the later process. However, when the subjects generated their designs using computers, they chose one or two analogical ideas as their design base at the beginning. Then, they put other analogical ideas through the process, and these analogical ideas were distributed throughout the whole process.

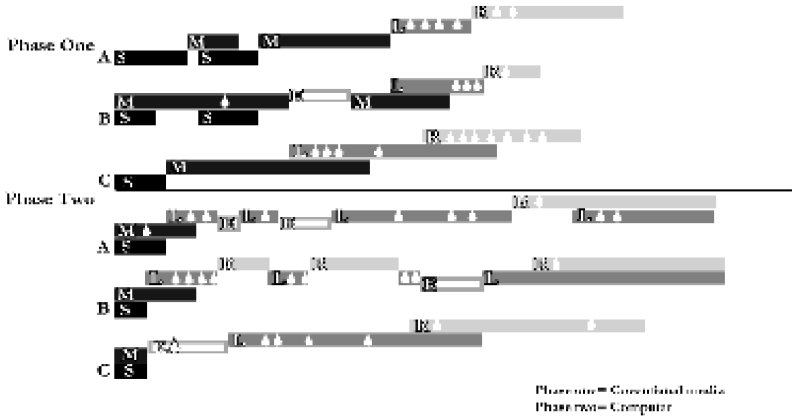


Figure 4. The appearance of analogical ideas.

While discussing the relationship between the stages and the appearance of ideas, the author would like to point out an interesting situation in the coding results. In phase one, most analogical transfers happened in the learning and representation stages, but the analogical transfers appear in the selection, mapping, learning and representation stages in phase two.

4.4. PHENOMENON FOUR

Every medium possesses its own characteristics, which cause the analogical thinking process and design results to be diverse. Conventional media can assemble analogical ideas and computer media can expand analogical thinking.

Designers using conventional media can draw many sketches and gather analogical ideas at one time. Assembling keywords and sketching helps designers clarify their various analogical ideas. At the beginning, they draw diagrams that were similar to the source organisms and then finished off these diagrams with a few deft strokes. Because these free form strokes represent the train of thought of the designer, every stroke may be the inspiration for the next sketch, and designers can find interesting ideas form these diagrams. They can combine them to new diagrams and transform the original source to a new condition. It is a step-by-step process where the final design result is decided by the previous study. Figure 5 is the mapping process of subject A.

Figure 5. The mapping process of subject A.

Computers allow the designer to explore numerous creative potential. When designers create their designs with computers, they know the design direction but cannot predict the result. Designers are proficient on the computer can manipulate the application's commands and parameters to change the form or other spatial functions. Using mathematical algorithms, the computing tool has an enormous capacity to describe things of an extremely diverse nature. Figure 6 shows Subject B changes the shape of his model by altering the control parameter.

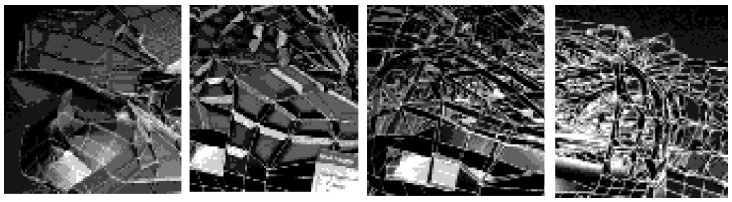


Figure 6. Subject B changes the shape by controlling parameters.

5. Conclusion and Future Studies

According to the analysis results, analogical thinking is an interaction between designers, analogical sources, design targets, and design media. Designers play the key role in the analogical thinking process because they can choose and transfer any idea. Analogical depth also depends on the designer's imagination and creativity. The choice of design media could affects the design process and reveals the variability of analogical thinking.

This research is a preliminary understanding of analogical thinking in the design. In this research, the analogical sources are limited to the organism. Paying attention to too many sources would distract from our main problem, as organic analogical sources are not comprehensive enough. Further study will focus on various types of analogical sources. It is also hoped that this research has to some extent established a framework for the analogical thinking process in the design field.

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