

THE DUAL EFFECTS OF INSPIRATION SOURCES

--- DESIGNERS' USE OF ANALOGY IN CREATIVE DESIGN

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ABSTRACT:

Architects employ various media as “inspiration sources” in their design process. This study investigates the effects of different inspiration sources on creativity. We found that “inspiration sources” can facilitate creativity, but they can also inhibit creativity and cause “fixation.”

This paper describes the protocol study of three subjects' conscious uses of 5 different types of inspiration sources (keyword, diagram, plan, sketch and precedent photo correspondingly) while performing the same design task. The results show that text and sketch are helpful inspiration sources for both novice and expert designer. We developed the “*Extended Linkograph*” and “*Distance Graph*,” for this research, to investigate the different patterns of analogical reasoning among different inspiration sources and subjects with different levels of expertise.

KEYWORD: sources of inspiration, creativity, fixation

1. MOTIVATION

It is widely accepted that architects draw various sources of inspiration from their daily lives. The term “inspiration sources” refers to all conscious uses of previous designs, and other objects and images, which constitute the reference for the solution to the problem that is to be solved (Eckert, Stacey and Clarkson 2000). The sources may take the form from basic geometrical shapes, abstract texts to images and works of art; objects and phenomena from nature and everyday life, as well as architectural precedent pictures; design sketches; diagrams and technique drawings (plans & sections). In the design process, designers tend to retrieve knowledge of a familiar problem or situation (called *source analog*) that is relevant to a given problem (called *target*) and transfer that knowledge to solve the current problem (Gentner 1983, Vosniadou 1989). This way of thinking and reasoning is called “analogical reasoning“. It appears to play an important role in an architecture student’s learning and the architects’ professional development (Goldschmidt 2001, Casakin 2004).

There is currently a growing body of knowledge related to analogical reasoning and creativity (Goel 1997, Gentner & Markman 1997, Hofstadter 1995). However, there are some interesting questions still remain to be answered:

- 1) To what extent, can the inspiration sources help designers enhance their creativity?
- 2) To what extent, will the inspiration sources constrain the designers’ imagination and creativity?
- 3) What are the different effects of various inspiration sources on analogical reasoning and creativity?
- 4) Do novice and experienced designers respond to inspiration sources differently? If so, how are they different?

1. 1. ANALOGICAL REASONING & CREATIVITY

Before we answer these questions, let’s briefly review related work on analogical reasoning and creativity. Analogical reasoning has been the focus of Artificial Intelligence research and design studies. It is considered to play a key role in innovation and creativity. Broadbent (1973, p.35) argued that “analogical design is the most potent source of creative ideas in architecture“. Hence,

Architecture students are often trained to collect precedent designs and to learn from them. They store, remind and transfer the elements of precedents to the new design problems. The selected design elements can be components, relations between components, or configurations of components and relations (Goel 1997). For example, the analogy may be the imitation of certain features, forms, or the transfer of topology, even design principles.

According to the content of the knowledge transferred, researchers have categorized analogy into “surface analogy” and “deep (structural) analogy” (Genter 1983, Vosniadou 1989). These two types of analogies represent different degrees of abstraction. “Structural analogy” is believed to be related to the transference of a higher hierarchy of knowledge. Therefore, it may lead to more creative design (Casakin 2004). Similarly, Goel (1997) stated that, “the degree of creativity depends on the extent of the problem and solution reformulation, and the transfer of knowledge from different knowledge sources to the design problem.” The distance between “source” and “target” is said to be related to the level of difficulty of transferring the analogy (Johnson-Laird 1989). In summary, creativity seems to be associated with analogy transfer; with the degrees of abstraction; and the distance between “source” and “target.”

1.2. DIFFERENT MEDIA OF INSPIRATION SOURCES

Based on the degrees of abstraction and the distance from the “source” to “target”, the “inspiration sources” can be categorized as “between-domain” sources and “within-domain” sources (Casakin 2004; Goldschmidt 2001). Between-domain sources refer to the sources that belong to different and distant domains from the target problem. Within-domain sources refer to the sources that are embedded in the same or a closely related domain from the target problem (Casakin 2004), that contains more domain-specific knowledge. In this paper, we will focus on the domain of architecture design. Within-domain sources for this study are materials more closely or directly related to architecture.

With this definition, the media of between-domain sources include: 1) abstract texts, 2) images and works of art, and 3) objects and phenomena from nature and everyday life. The media of within-domain sources include: 1) basic geometrical shapes and diagrams, 2) architectural technique drawings (plans & sections), 3) architectural precedent design sketches, and 4) architectural precedent pictures.

2. DUAL EFFECTS OF “INSPIRATION SOURCES”

How will various “inspiration sources” impact creative design? We argue that “inspiration sources” can cause dual effects in design experiences. One is the positive effect that helps to inform new designs. Designers generate innovative designs by either transformation, or derivation of the “inspiration sources”. Another one, is the negative effect that produces context or constraints for the new design. That is, inspiration sources may also contribute to the occurrence of “a design fixation”. Fixation is a common phenomenon in perception, problem solving and design. It means that once an interpretation has been reached, it is difficult for designer to see alternatives (Suwa et al. 2001).

2.1 DIFFERENT EFFECTS OF DIFFERENT INSPIRATION SOURCES AS DESIGN AIDS

Several researchers have examined the different functions of the “inspiration sources” as design aids. Some of them have focused on the function of “inspiration sources” as visual stimuli. For instance, Malaga (2000) designed an experiment for participants to generate ideas in response to a specific task, by showing them word, picture, and combined word and picture stimuli. He reported that pictures could elude more creative ideas than words and combined stimuli. Kokotovich and Purcell (2000) examined the different impacts on creativity of two-dimensional shapes and three-dimensional forms on different professionals. Their subjects included graphic design, industrial design, and law students. They found that the subjects were more sensitive to the types of media more typically used in their domain. For example, graphic design students performed better with two-dimensional shapes and industrial design students performed better responding to three-dimensional forms.

Research also showed that novices and experts perceive visual stimuli differently. Expertise is found to affect the inferences that can be made from “inspiration sources”. Suwa and Tversky (1997) argued that professional architects are more adept at seeing functional and abstract properties in the sketches than students. Novic (1988) claimed that experts drew analogies based on structural similarities while novices tend to retrieve surface features from inspiration sources. Casakin and Goldschmidt (1999) studied how experts and students use visual analogy differently in solving well-defined and ill-defined problems. They found that, for well-defined problems, only experienced designers benefited from the visual displays. For ill-defined problems, both experts

and students improved their design performance with the presence of visual displays, especially when given explicit instruction to use analogy.

2.2 DIFFERENT EFFECTS OF DIFFERENT INSPIRATION SOURCES AS DESIGN FIXATION

As aforementioned, inspiration sources can serve as visual stimuli to improve design performance and creativity. However, inspiration sources may also impede creativity. Studies revealed that by showing students a diagram or a related concept associated with a part of a diagram for students to free their imagination (Jansson & Smith 1991). Howard-Jones (1998) found that the rate of generating new interpretations from an ambiguous drawing decreased after the first minute of trying. The premature commitment to a particular problem solution is called “fixation” in psychology. Evidence has shown that design fixation may be associated with seeing pictorial representations of possible design solutions. The forms of pictorial representation vary from the pictures of design precedent to different types of diagrams. Purcell and Gero (1996) have explored the effects of fixation by applying the modified Jansson and Smith’s experiment on mechanical engineers and industrial designers. They found that mechanical engineers became fixated when they were forced to rely on everyday knowledge or were shown the principle involved in an innovative design. However, we do not know if the fixation exhibited by these engineers and designers would also apply to architecture designers. Furthermore, there are opportunities for us to study the difference of the effects of various media (keyword description & pictorial representations etc.) on design fixation.

2.3 EVALUATION OF CREATIVITY AND DEGREES OF FIXATION

Several studies have proposed ways to evaluate creativity and the degrees of fixation. Goldschmidt and Smolkov (2006) used judges to give subjective scores for originality, practicality and the general quality of design. The design solution is considered creative if both the sum of its originality scores and practicality scores are at least 11 out of 15 (maximum). Purcell and Gero (1996) proposed “frequency of occurrence” as the index of the effects of fixation. They believe that the more the features associated with the example appear in the design product, the more a fixation situation may occur.

Goldschmidt (1989) presented *Linkograph* as a method to evaluate the productivity of design. In the *Linkograph*, the sequence of moves is represented by hollow dots aligned in a horizontal line and the links are the nodes at the intersections of the diagonal network lines connecting two related moves (Fig.1). She found that the distribution of links among design moves can reflect the general pattern of design process. The *Linkograph* of more productive design would display higher *link indexes*, more *chunks* and more *webs*. In her definition, *link index* means the ratio between the number of links and the number of moves that are generated in a design cycle. A *chunk* refers to “the block of links among successive moves that link exclusively among themselves and barely interconnect with other moves”. A posterior design move has a strong linkage with an anterior move. A *web* refers to a relatively small number of moves with a large number of links.

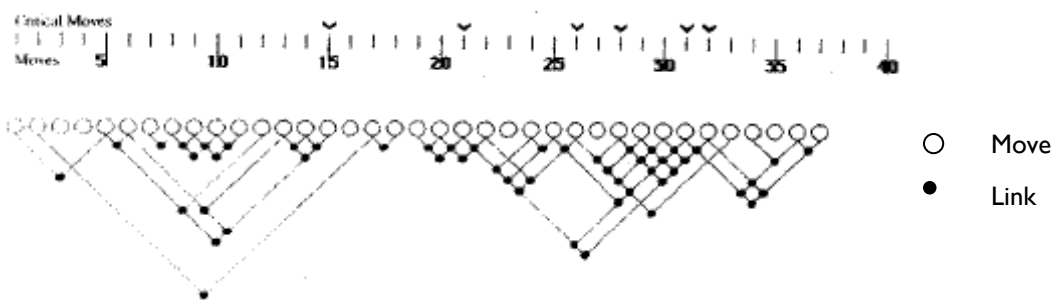


Figure 1: Linkograph of design cycle (Goldschmidt, 1989)

However, as Goldschmidt has identified, the present *Linkograph* does not include the typology of design moves. To examine the dual effects of inspiration sources, we need to represent both the breadth and the depth of the problem space explored in the design process. Therefore we proposed an approach called “*Extended Linkograph*” that combines the concepts of “*lateral transformation*” (LT) and “*vertical transformation*” (VT) (Goel 1995) with the current “*linkograph*”. A “*lateral transformation*” refers to movement from one idea to a slightly different idea, or an alternative idea. A “*vertical transformation*” is a move from one idea to a more detailed or mature version of the same idea (Goel 1995). In other words, a LT is a process that broadens the problem space while a VT deepens the problem space. Here we used LT and VT to represent the linkages between each “*move*” in design. In the “*Extended Linkograph*”, the first move is the inspiration source. The following moves refer to the images generated in the subsequent design sub-session. The moves are aligned with the previous move either horizontally or vertically, depending on the direction of the linkage between them (LT & VT). VT is expressed in vertical axis and LT is expressed in horizontal axis (See Fig. 2). For example, in Fig.2, Subject 3, S3-T-N2-1 is based on the LT of S3-T-N1. So they are arranged in a horizontal line. By contrast, S3-T-

N2-4 and S3-T-N2-3 and S3-T-N2-2 are based on VT of S3-T-N2-1. So they are arranged in a vertical line. In this study, we coded the drawings according to the subject, the experiment sub-session, and the numbers of solution type and drawing. For instance, “S3-T-N2-4” refers the fourth drawing of the second solution generated by Subject 3 in the “Text as inspiration” sub-session. To differentiate “plan” and “photo”, we use “PL” as abbreviate of “plan” and “PH” as abbreviate of “photo”. The detailed coding scheme is described in the third session of the paper (See Table. 1).

Drawing Type	Medium	Design Focus	Distance value
D1: Plan	M1: Pencil sketch on tracing paper	F1: Direct reference	1
D2: Section	M2: Pencil sketch on blank paper	F2: Formal variations	2
D3: Elevation	M3: Hard-lined on tracing paper	F3: Functions Variations	3
D4: Isometric	M4: Hard-lined on blank paper	F4: Spatial Variations	4
D5: Perspective	M5: Other	F5: Surroundings, context consideration	5
D6: Other		F6: Other	6

Table 1: Coding scheme for the drawings generated during the experiment

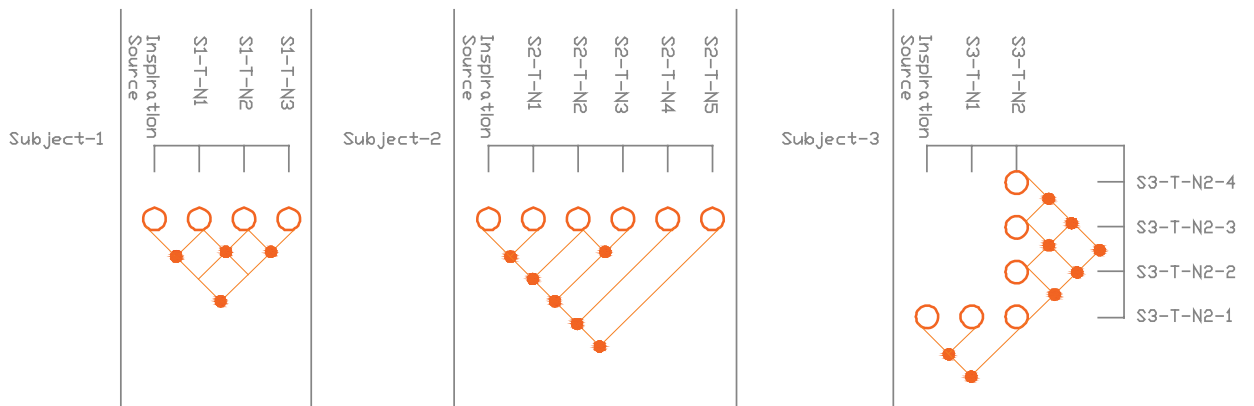


Figure 2: *Extended Linkograph* analysis on the design of the “text as inspiration” sub-session

The distribution pattern of “*Extended Linkograph*” can reflect the creativity and fixation in a design cycle. The more creative the design is, the more numbers of alternatives and more *chucks* and *webs* are displayed in the “*Extended Linkograph*”. In addition, the more linkages are connected to the adjacent previous alternatives, the more possibly the designer may be in a fixation situation. More linkages represent that more features associated with the previous move appeared in the latter alternatives. The frequent repetition of elements of the previous alternative is a sign of fixation. For example, the “*Extended Linkograph*” of Subject 1 in Figure 2 represents a tendency of fixation. Subject 2 and Subject 3 show more productive design process. The reading of the “*Extended Linkograph*” is “stair-wise”, starting from left to right, from bottom to top.

The virtue of “*Extended Linkograph*” is that it differentiates the links between moves as LT and VT. It helps to reveal the productivity in both lateral and vertical dimension. For example, although in the “text as inspiration” sub-session (Fig.2), Subject 3 generated less design alternatives than Subject 1 (2 solutions versus 3), Subject 3 was more creative in another sense, because he presents more in-depth exploration in one option than simply seeking alternatives.

However, the “*Extended Linkograph*” cannot quantify the degree of creativity and fixation. Hence we developed another criterion called “*Distance Graph*”, which mapped the “distance between the product alternatives” in X-axis and “distance between the inspiration source and product” in Y-axis. The distance was determined by the value based on the degree of development, which was correlated with the design focus. The value varied from 1-6. We defined “direct reference” as 1, “formal variation” as 2, “functional variation” as 3, “spatial variation” as 4, “surroundings and context consideration” as 5, “other consideration” as 6. For instance, if the drawing S1-T-N-1 was “functional variation” of the “inspiration source”, then the value in Y-axis was 3. While if the drawing S1-S-N-2 was a new alternative, which was based on the “formal variation” of the previous drawing S1-S-N-1, then the distance between drawing S1-T-N-1 and S1-T-N-2 was 2 in X-axis (See Fig.3).

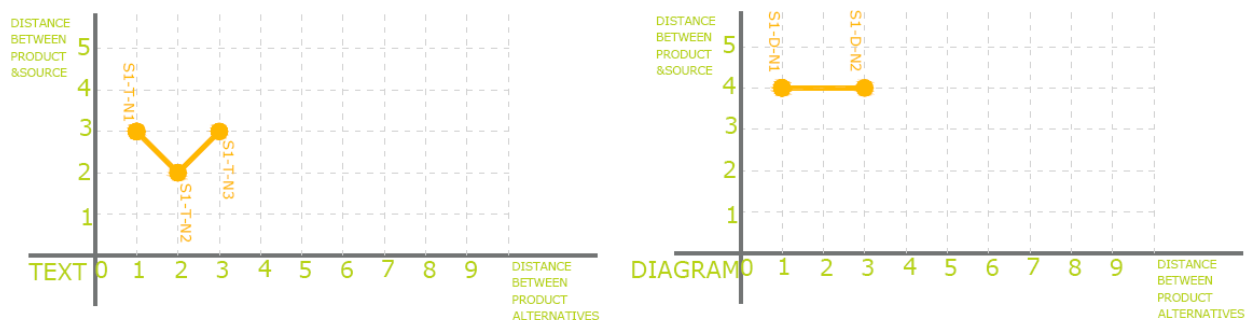


Figure 3: Example of “Distance Graph” on design experiment of Subject 1 in “text” and “diagram” sub-session

3. THE EXPERIMENT

Now, let's look at the experimental setting and the design task. We planned the experiment to empirically examine the effects of different inspiration sources on design performance and creativity. Three students were asked to solve a simple and relatively well-controlled design problem, in this case, a design for a single family house. Each experiment was composed of five sub-sessions. They were provided five different inspiration sources (keyword, diagram, plan, sketch and precedent photo correspondingly). The design process was videotaped and followed by a short interview.

3.1 EXPERIMENTAL SETTING

The designers were asked to perform the experiment in their daily work settings to minimize the impact of the physical environment on creativity. Studies have shown that environments with high creative clues, such as complexity and visual details, will greatly impact people's creative potential (McCoy and Evans, 2002). We chose to conduct the experiment in their daily work environment so that physical environment would not impact their design performance significantly.

Subjects were tested individually. The experimenter presented the design problems and explained the procedure to the participating designers and did not intervene during the design process. Participants were given sheets of plain Xerox paper as well as tracing paper. They could either sketch or make hard line drawings. They could either describe what they were doing when designing or choose to work in silence. The design activities were videotaped with a single camera pointed at the working surface. We interviewed the participants after they finished the design tasks. They were asked to report their subjective evaluation on their design performance and tell us how they use different inspiration sources in the design process. They were also asked to choose three most important inspiration sources in their real design experience from the 8 options provided by the experimenter. All graphic output was collected and indexed according to the coding scheme developed from a previous study (Neiman, Gross & Do, 1999).

Table 2 shows an example of how designers' drawings are indexed and coded. As mentioned in section 2, each drawing is indexed according to subject ID, the inspiration source for each sub-

session, of the type of medium and the focus of the drawing. We identified the design focus and assigned the “Distance Value” for each drawing. We also coded the different drawing types and medium to see how they were related to the phase of design development.


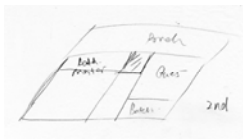
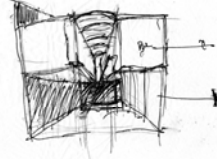

ID#	Drawing	Drawing Type	Medium	Focus	Distance Value
S2-T-N1		D1: Plan	M1: pencil sketch on tracing paper	F3	3
S1-S-N1		D4: Isometric	M1: pencil sketch on tracing paper	F3	3
S3-Plan-N3		D5: Perspective	M3: Hard-lined on tracing paper	F4	4
S2-Photo-N1-2		D3: elevation	M1: pencil sketch on tracing paper	F5	5

Table 2: Example of coding of drawings

3.2 PARTICIPANTS

Three subjects participated this experiment. Their background information was coded. For easier reference, we assign pseudo names to each of them in this paper. Subject 1, Mary, is a PhD student in Industry System & Engineering. She has no prior architectural design experience. Subject 2, Sam, is a first year PhD student in the College of Architecture. He has 7 years of architecture education and 5 years of professional design practice experience. Subject 3, Bob, is a second year Master student in the College of Architecture. He has 7 years of architecture education and 8 years of professional practice.

3.3 DESIGN TASKS

The design task was to design a single-family house. The area of the house was around 1500 square feet (around 135 square meters). The program of the house included two bedrooms and two bathrooms, one for the master bedroom and one for the guest room. The total design time was half an hour with five sub-sessions. For each sub-session, the subjects were asked to generate as many schemes as they can within 6 minutes, based on the different given inspiration sources.

We gave one specific inspiration source to the subjects in each sub-session. All five inspiration sources were derived from Frank Lloyd Wright's Frederick-C-Robie house. They ranged from abstract to detailed picture. The first inspiration source was the description key words of the physical characters of the house. They were "three rectangles, symmetric & asymmetric". The second inspiration source was a diagram composed of five rectangles, depicting the spatial propensity of the Robie house (See Fig.4). The third was the floor plan of its first floor (See Fig.5). The fourth was the exterior sketch rendering of the Robie House (See Fig.6). The last one was the black and white exterior photo of the Robie house (See Fig.7). The sequence of showing text-diagram- plan-sketch-photo, was based on the degree of abstraction and the distance of the source to the target.

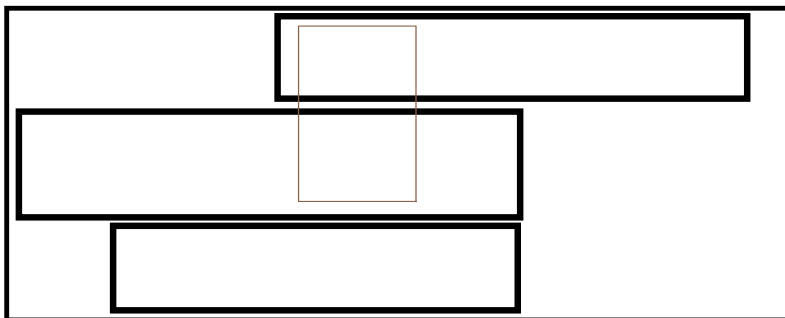


Figure 4: Diagram of the Robie house

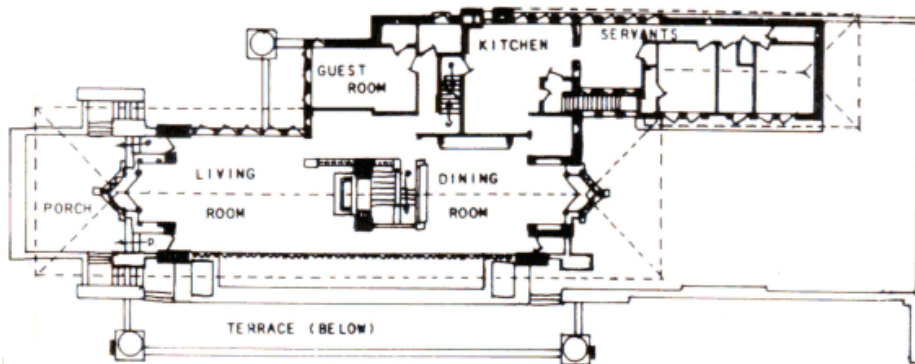


Figure 5: Floor plan of the Robie house's first floor (Source: <http://www.delmars.com/wright/flw8-5.htm>, Copyright: Frank Lloyd Wright Foundation)

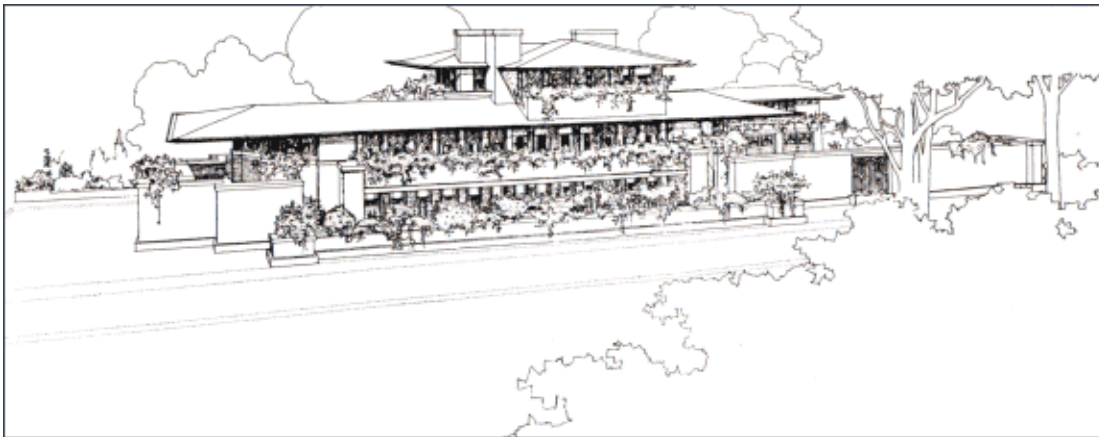


Figure 6: Exterior sketch rendering of the Robie house (Source: <http://www.delmars.com/wright/flw8-5.htm>, Copyright: Frank Lloyd Wright Foundation)



Figure 7: Photo of exterior of the Robie House (Source: Great Buildings Collection)

4. RESULTS

The results of the experiment showed different reactions to the inspiration sources within subject and the different patterns of analogy among subjects. We will first present the overview of the experiment results and then apply the “*Extended Linkograph*” and “*Distance Graph*” to represent and analyze the results in detail.

4.1. DESIGN EXPERIMENT ON SUBJECT 1

Subject 1, Mary, showed low productivity in creating design alternatives. In “diagram” and “plan” session, she exhausted design alternatives before she reached the time limit.

00:11:32, “I don’t think I have any more ideas.”

During the “photo” session, she failed to create any design based on the inspiration source. She expressed her frustration in the follow-up review.

00:21:25, “I think all of them look similar, not too much difference. I really feel frustrated.”

High similarity was found among her design alternatives. Most of them were “surface analogy” from the inspiration source (Fig. 8a-8b). She traced on top of the images given, followed the shapes of the inspiration source and then tried to arrange the functions inside.

00:19:12, “This material (plan) already gave me a lot of information. I just need to copy them down.”

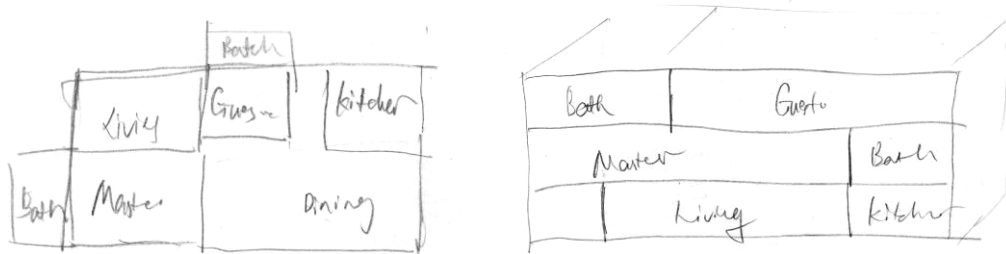


Figure 8a (left): sketch by Mary in “plan” session (SI-PL-N2); Figure 8b (right): sketch by Mary in “diagram” session (SI-D-NI)

Mary stated that using both sketch and text helped her generate more design alternatives. Text gave her more free space to design. She said that sketch is helpful because it provided her some general information “without too many details”. She explained her point of view by comparing the plan to the sketch.

00:20:15, “Both of them (plan and sketch) give me detailed information. But this one (plan) perhaps is too detail for me. While this one (sketch) give me certain information and allow you to think more about (the design of) yourself.” ...“It (the sketch) reminds me a real picture. I will think about a real house.”

Mary reported that the diagram and architecture floor plans were too constraining for her design and created a bottleneck, and felt that the diagram was the most inhibiting to her design. She had no architecture training background, and no domain knowledge about the famous Robie House. As a result, she failed to recognize that the inspiration sources were from the same design precedent. Mary could not match the photo with the sketch of the Robie house. Therefore, the photo did not help to clarify the interior space:

00: 27:46, “I don’t think they (photo and sketch) are similar.” “The exterior photo seems not very useful. I cannot imagine the interior space.”

In summary, as a non-architect, Mary had to draw analogies based on her everyday experiences. She found text and sketch as helpful inspiration, since they were the most closely related to her everyday knowledge. We noticed that she preferred sketch over photo as her inspiration. The reason may be that photo contains too much detailed information that distracted her design thinking. Diagram constrained her creativity because she lacked the domain knowledge to understand the spatial relationship embedded in the diagram. It is hard to make a “surface analogy” from a diagram, when the diagram only provides structural information, Mary couldn’t come up with new design alternatives from the inspiration source.

4.2. DESIGN EXPERIMENT ON SUBJECT 2

Subject 2, Sam, showed a higher productivity in his designs than Mary. In the “text”, “diagram” and “plan” sessions, he focused on the formal transformation and the functional arrangement. The “sketch” and “photo” session extended his exploration to spatial transformation and the context of surrounding environment. His sketches expanded from just plan view to both plan and elevation

views. The topology elements (e.g. change of level) and plants were included in his drawings (Fig. 10-11).

00:30:05, “Because you discover some elements that are outside the design itself, maybe the landscape or the surrounding...”... “You could see the whole context of the surrounding.”

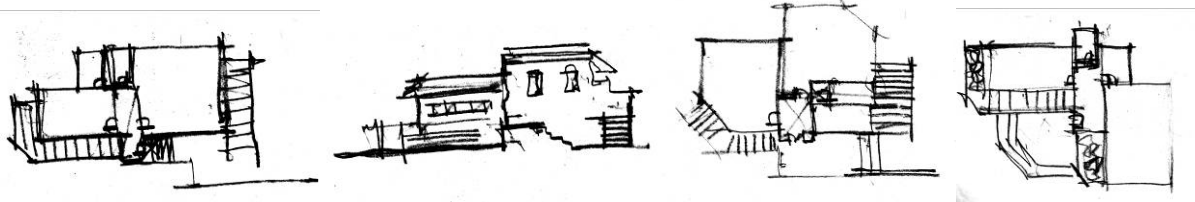


Figure 9a-9d: sketch by Sam in “plan” session (S2-PL-N1-1, S2-PL-N1-2, S2-PL-N2, S2-PL-N3)

For Sam, sketches and photos were the most helpful to his design. He claimed that they were more helpful in aiding him to generate more in-depth ideas, and provided more details than more design alternatives. At that stage, he was “not looking for or considering more alternatives”, but concentrating on developing the ideas captured from the given “sketch” and “photo”. They provided more information, and at the same time, gave him more constraints.

Sam identified text as the most important inspiration source in the experiment. He said those key words were open-ended and allowed more development possibilities. He thought diagrams created more obstacles to his design. Although, he realized the five different inspiration sources were from the same building, he perceived each differently. He described having difficulties in capturing the geometry from the diagram because it was too abstracted.

00:34:07, “You get some abstract concepts from it...But you get to need more time to think that, how can I apply them to my design, what do I capture from the diagram.”

In short, Sam found that text gave him space to create more alternatives, and that sketches and photos helped him explore design further in more detail. It was difficult for him to draw an analogy from the diagram, because he tried to establish a “structure analogy” between the diagram and his design. He found it hard to extract principle from the diagram in a short time span.

4.3. DESIGN EXPERIMENT ON SUBJECT 3

Subject 3, Bob, produced fewer alternatives but more depth in design exploration. He made a distinction between “development tools” and “inspiration tools”. Once Bob recognized the case as Wright’s Robie house, he started to relate his design to this precedent. The content and the idea of the precedent became the dominant idea in his new design. He became fixated after the third sub-session (plan as inspiration).

00:36:21, “You will go for that and imitate the idea. At the moment you recognize it, you got stuck with his idea.”

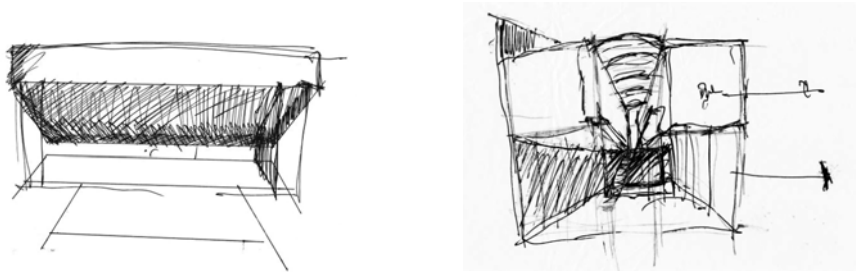


Figure 10a (left): sketch by Bob in “photo” session (S2-PH-N2); Figure 10b (right): sketch by Bob in “plan” session (S2-PL-N2)

Similar to Mary and Sam, Bob thought that text and sketch were helpful inspirations for his creative design. Words “opened a lot of doors for him,” while sketches gave him flexibility to read and changed the way he saw things.

4.4. COMPARISON OF THREE SUBJECTS’ DESIGN PERFORMANCE

This section compares three subjects’ design performance. In “text” session, Mary generated 3 design alternatives composed of 3 drawings, Sam generated 5 alternatives composed of 5 drawings, and Bob generated 2 alternatives composed of 3 drawings. In “diagram” session, Mary generated 2 design alternatives composed of 2 drawings, Sam generated 5 composed of 5 drawings, and Bob generated 2 alternatives composed of 3 drawings. In “plan” session, Mary generated 2 design alternatives composed of 2 drawings, Sam generated 4 composed of 4 drawings, and Bob generated 3 alternatives composed of 6 drawings. In “sketch” session, Mary generated 1 design alternatives composed of 1 drawing, Sam generated 2 composed of 4 drawings, and Bob generated 1 alternative composed of 5 drawings. In “photo” session, Mary

failed to generate any design, Sam generated 3 composed of 4 drawings, and Bob generated 1 alternative composed of 2 drawings. The results are presented in Table 3 and 4 below:

	Text	Diagram	Plan	Sketch	Photo
S1	3	2	2	1	0
S2	5	5	4	2	3
S3	2	2	3	1	1

Table 3: Different numbers of design alternatives created by different subjects in each sub-session

	Text	Diagram	Plan	Sketch	Photo
S1	3	2	2	1	0
S2	5	5	4	4	4
S3	3	3	6	5	2

Table 4: Different numbers of images created by different subjects in each sub-session

In the questionnaire about “what are the three most important inspiration sources you would look for in your real design experience”, we listed eight different types of inspirations. They are “basic geometric shapes”, “abstract texts”, “works of art (photography, painting & movie)”, “physical object in everyday life”, “architectural precedent photos”, “design sketches”, “diagrams”, “technique drawings” (plans & sections etc.). Mary chose “architectural precedent cases pictures”, “design sketches” and “technical drawings”. Sam chose “works of art”, “architectural precedent photos” and “design sketches”. Bob chose “basic geometric shapes”, “abstract texts” and “design sketches” (See Table 5).

	1. Basic geometric shapes	2. Abstract texts	3. Works of art	4. Objects in everyday life	5. Architectural precedent photos	6. Design Sketches	7. Diagrams	8. Technical Drawings
S1								
S2								
S3								

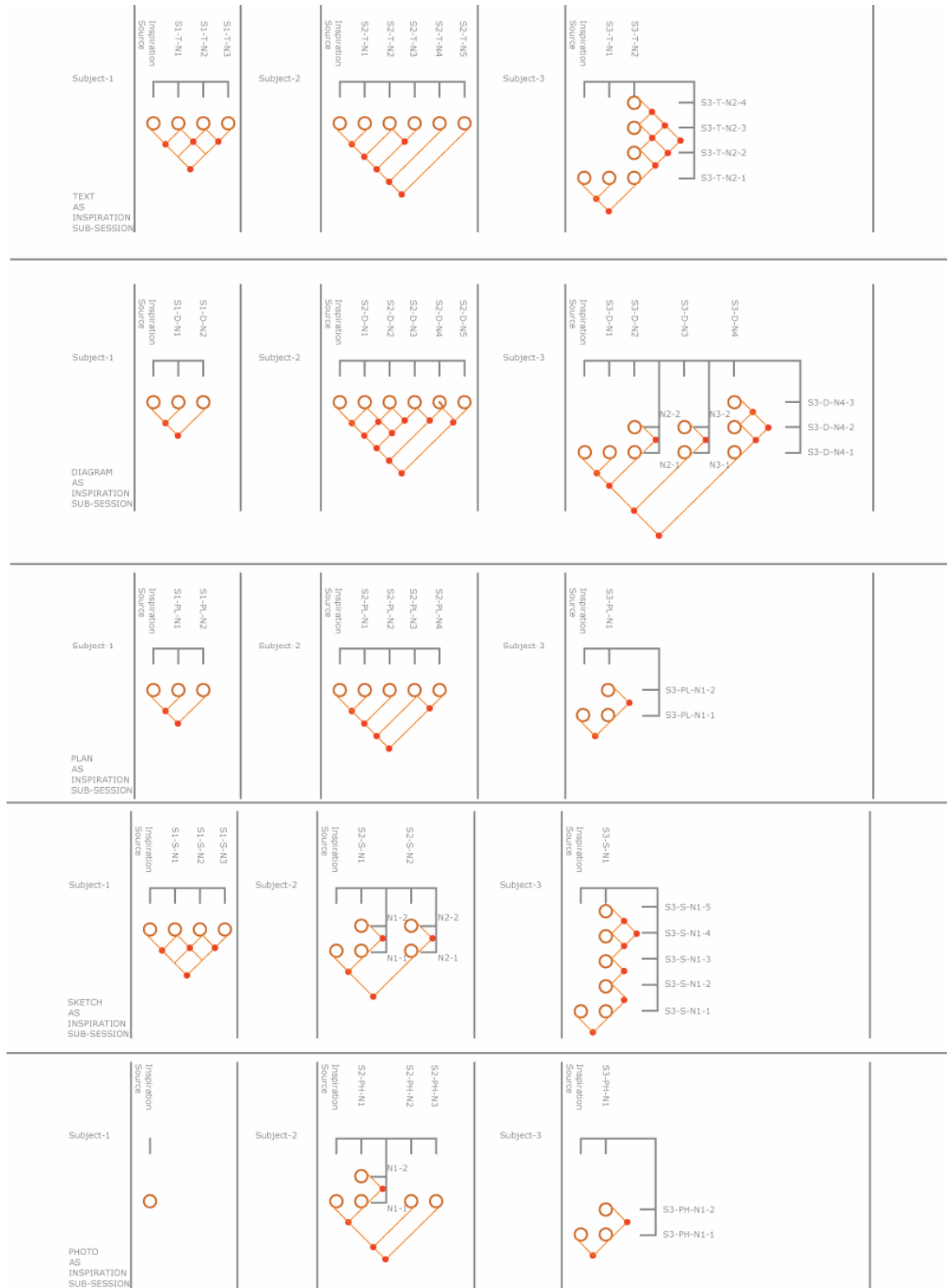
Table 5: Different choices made by the subjects on the most important inspiration sources in real design experience

4.5. “EXTENDED LINKOGRAPH” AND “DISTANCE GRAPH” ANALYSIS

Here we used the “*Extended Linkograph*” and “*Distance Graph*” to represent and compare the whole design process. For both “*Extended Linkograph*” and “*Distance Graph*”, three subjects’ design processes on each sub-session are placed together along the horizontal direction. The different effects of various “inspiration sources” are compared along the vertical direction (Fig.14, 16). From the “*Extended Linkograph*”, we can tell that Sam and Bob are more productive and creative than Mary, since there are more *chunks* and *webs* in the graph. Bob has more VT and shows more obvious earlier fixation than Sam. The result is consistent with Bob’s self reflection that recognizing the Robie house constrains his imagination. For the difference of variant sources, we find that as all the subjects have identified text and sketch to be more helpful for them to generate more alternatives and in-depth design. Plan and photo do not work well as inspiration sources. The reason may be that the plan and photo contain complex and multiple layers of information. It is difficult to extract the relevant elements from them. For diagram, three subjects have different responses. Bob and Sam show better performances over Mary. Sam has more recurrences of elements from previous moves, and therefore displays a stronger tendency of fixation over Bob.

The “*Distance Graph*” reveals that the novice and experts draw analogies from different levels (Fig. 14, 15). Mary’s analogy is in the lower level “surface analogy” since distance value between her design and the original source are low. Sam and Bob tend to draw “structural analogy” because they have overall higher distance values in the Y-axis.

Figure 11: “Extended Linkgraph” analysis on the experiment based on different sub-sessions



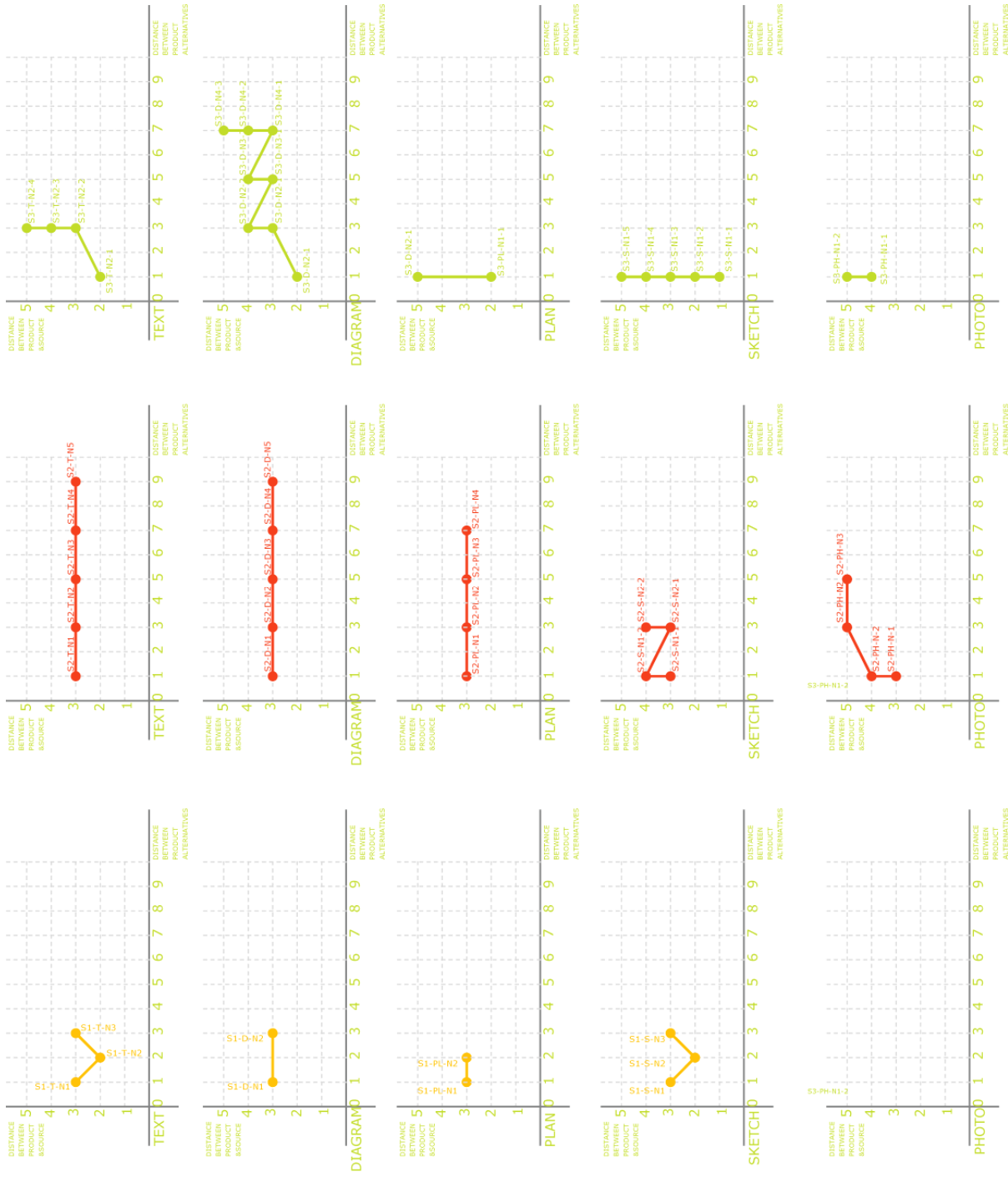


Figure 13: Compare "Distance Graph" of three subjects' design performance in each sub-session

5. DISCUSSION AND FUTURE WORK

The preliminary findings, summarized here, are based on “*Extended Linkograph*” and the “*Distance Graph*”:

1) Expertise affects how inferences can be made from inspiration sources.

Based on the same “inspiration sources”, expert designers generated more interpretations than novice designers. Both groups respond differently to “inside-domain” and “between-domain” inspiration sources. Because text is a “between-domain” source, the analogy to text is mainly based on everyday experience. Therefore, novice designers and experienced designers are similar in their use inspirational sources. Text has no obvious fixation effect for either of them.

2) Sketches are highly related to creativity.

Sketch is found to be the most helpful and important inspiration source for both expert and novice designers. The reasons may relate to the abundant information provided, the ambiguity of that information, and the fact that sketches have fewer distracting details than photos. Expert and novice designers both found sketches inspiring.

3) Diagrams’ impact on creativity varied depending on experience.

Diagrams were found to constrain creativity for novice designers. But, the fixation effect did not appear to impact expert designers as seriously. Even though Bob complained that the diagram constrained him, he actually generated more design alternatives than Sam and Mary in the “diagram” session.

4) Expert designers prefer depth over variations in design.

Although the experiment asked for generation of as many design alternatives as possible, expert designers tended to go deeper into design, rather than making more design variations. They extracted multi-layered information from the inspiration sources. Their exploration on the design option was developed through different dimensions (plan, elevation, perspective etc.).

5) Experts tend to choose abstract and distant analogy sources

With the increase of experience, designers tended to look for more abstract and distant inspiration sources for enhancing creativity. For instance, Bob chose “basic geometrical shape” and “abstract

text” as the important inspiration sources, while Mary chose “architecture precedent photos” and “technical drawings” as her inspiration sources. In addition, experts tended to make higher level “structural analogy” while novice designers tended to make “surface analogy” from the source.

In sum, we designed a small-scale experiment to empirically examine the different effects of various inspiration sources in creative design. We proposed “*Extended Linkograph*” and “*Distance Graph*” to represent the pattern of design process. We found that text and sketch can facilitate innovative design and avoid early fixation. Experience and domain knowledge was relevant in making valid and higher level analogies. A future expanded study would use a broader range of inspiration sources and a larger and more diverse population of participants. Different design professions should also be included to explore the influence caused by their domain knowledge. For example, graphic designers may be more sensitive to 2D drawings, while industrial designers and architects may be more susceptible to 3D imaginary.

BIBLIOGRAPHY

Broadbent, G. (1973). *Design in architecture: architecture and the human sciences*. London; New York: Wiley.

Casakin, H. (2004). Visual Analogy as a Cognitive Strategy in the Design Process. Expert Versus Novice Performance. *J. of Design Research*, 4(2).

Casakin, H., & Goldschmidt, G. (1999). Expertise and the use of visual analogy: implications for design education. *Design Studies*, 20(2), 153-175.

Do, E. Y. -L. (1995). What's in a diagram that a computer should understand. *Computer Aided Architectural Design Futures'95*, 469-482.

Do, E. Y. -L. (1998). *The Right Tool at the Right Time*. Georgia Institute of Technology. Ph.D dissertation.

Eckert, C. M., Stacey, M. K., & Clarkson, P. J. (2000). Algorithms and Inspirations: Creative Reuse of Design Experience. *Proceedings of the Greenwich 2000 Symposium: Digital Creativity*, 1-10.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science*, 7(2), 155-170.

Gentner, D., & Markman, A. B. (1997). Structure mapping in analogy and similarity. *American Psychologist*, 52(1), 45-56.

Goel, A. K. (1997). Design, analogy, and creativity. *Expert, IEEE [see also IEEE Intelligent Systems and Their Applications]*, 12(3), 62-70.

Goel, V. (1995). *Sketches of Thought*. : Bradford Book.

Goldschmidt, G. (2001). *Visual Analogy: A Strategy for Design Reasoning and Learning*. *Design Knowing and Learning: Cognition in Design Education*. Elsevier. pp199-219.

Goldschmidt, G., & Smolkov, M. (2006). Variances in the impact of visual stimuli on design problems solving performance. *Design Studies*, 27(5), 549-569.

Hofstadter, D. (1995). *The Fluid Analogies Research Group. Fluid concepts and creative analogies: Computer Models of Mental Fluidity and Creativity*. Basic Books.

Howard-Jones, P. A. (1998). The variation of ideational productivity over short timescales and the influence of an instructional strategy to defocus attention. Paper presented at the Proceedings of the 12th Annual Meeting of the Cognitive Science Society, New Jersey.

Jansson, D. G., & Smith, S. M. (1991). Design fixation. *Design Studies*, 12(1), 3-11.

Johnson-Laird, P. (1989). Analogy and the exercise of creativity. In S. Vosniadou & A. Ortony (Eds.), *Similarity and Analogical Reasoning: what develops?* (pp. 313-331). Cambridge: Cambridge University Press.

Kokotovich, V., & Purcell, A. T. (2000). Mental synthesis and creativity in design: an experimental examination *Design Studies*, 21(5), 473-499.

Malaga, R. S. (2000). The effect of stimulus modes and associative distance in individual creativity support systems. *Design Support Systems*, 29, 125-141.

McCoy, J.M. and G.W. Evans, *The Potential Role of the Physical Environment in Fostering Creativity*. *Creativity Research Journal*, 2002. 14(3 & 4): p. 409-426.

Neiman, B., M.D. Gross, and E.Y.L. Do, *Sketches and their functions in early design. A retrospective analysis of a pavilion house*. 4th Design Thinking Research Symposium, DTRS99, Cambridge, MA, 1999.

Purcell, A. T., & Gero, J. S. (1996). Design and other types of fixation. *Design Studies*, 17(4), 363-383.

Stacey, M. K., Eckert, C. M., & McFadzean, J. (1999). *Sketch Interpretation in Design Communication*. *Proceedings of the 12th International Conference on Engineering Design*, 2, 923-928.

Suwa, M., & Tversky, B. (1997). What do architects and students perceive in their design sketches? A protocol analysis. *Design Studies*, 18(4), 385-403.

Vosniadou, S., & Ortony, A. (1989). *Similarity and Analogical Reasoning: what develops?* Cambridge: Cambridge University Press.