

Idea Generation with Precedents

New findings from semantic maps of designers' cognitive process

EunJin Kim*, KwanMyung Kim**

* School of Design and Human Engineering, UNIST, Ulsan, Korea, ejkim@unist.ac.kr

** School of Design and Human Engineering, UNIST, Ulsan, Korea, kmyung@unist.ac.kr

Abstract: Previous research has argued that more experience is better for idea generation. However, there is lack of sufficient evidence to explain why more experience is better, and how it is better. In order to suggest possible answers to these questions, this research aims to investigate the cognitive processes of designers during the idea generation process. Especially, the behaviour of utilizing prior knowledge and experience were examined comprehensively. Participants performed a design task while using the think aloud method. Based on data analysis, semantic maps composed of ideas, precedents and interpreters were constructed. By analyzing each semantic map, both qualitative and quantitative data was obtained. Result show two different types of thinking style which have different level of divergence. Data also implies operational capacity which limits the number of precedents that designers can utilize at once. Finally, the potential ability of ideas yielding other ideas was proposed.

Key words: *Design Thinking, Idea Generation, Cognitive Process, Precedents, Semantic Map*

1. Introduction

1.1 More is better. Is it true?

It seems like most recent research argues that more experience is better to generate creative ideas. Laxton (1969) argued that having a reservoir of experience and knowledge is the first skill that design students should acquire [5]. Hertzberger (2005) also recommended that students should experience more in order to expand their frame of reference [4].

Based on these result, many researches have been attempted to enhance the ability to utilize prior knowledge and experience by investigating the nature of designers' cognitive process. However, there is still doubt whether more experience produces better ideas or not. Furthermore, there is no sufficient explanation about what kind of knowledge and experience is helpful to generate valuable ideas. In order to explore the unknown territory of the idea generation process, this research utilized a think aloud method and created parametric data obtained by constructing semantic maps of the idea generation process.

1.2 Literature Review

As an effort to understand prior knowledge and experience for designers, Oxman (1990) suggested the ways in which prior knowledge is structurized in and utilized from our cognitive memory [9]. In daily life, most knowledge is obtained from specific contexts. She argued that newly obtained knowledge built a relationship

with prior knowledge in memory through generalization and typification. As knowledge is generalized and typified more and more, it becomes context-independent knowledge.

Among prior knowledge and experience, design precedents play a pivotal role in the design process [7]. Oxman (1990) also highlighted the 'design precedents typification' as 'one of the most significant typification' [9]. As Goldschmidt (1998) pointed out, designers do not try to demonstrate precedents for similar outcomes [3]. Instead of demonstrating them, designers use precedents in order to pull out information relevant to a design problem [10].

While designers generate design solutions, prior knowledge and experience is exploited in diverse parts of the whole design process. It works as a starting point which triggers initiation of design ideas [9]. It also provides guidelines and criteria to develop and evaluate solutions [3] [13]. In addition to contributing to a single design process, prior knowledge and experience assists designers to formulate their own beliefs and views about design [6]. According to Lawson (2004), designers identify their own guiding principles as their expertise develops with a growing pool of precedents. Based on these guiding principles, designers selectively choose useful ones from a huge pool of precedents which have been previously accumulated [6].

Although various aspects of prior knowledge and experience in design were investigated, few researches proposed directional suggestion to acquire expertise and facilitate creativity. How does embodiment of prior knowledge and experience support a productive generation process with creative outcomes? What is the meaning of design expertise in terms of cognitive properties in utilizing prior knowledge and experiences?

This research intended to investigate the cognitive behaviour of utilizing prior knowledge and experience in order to explore the implication for design ability and creativity. An empirical study was conducted with master students majored in industrial design. This approach was also novel since little research on this subject has been conducted in the field of product design.

Throughout this paper, the concept of episodic and semantic memory will be widely used. These terms are generally used in cognitive psychology to represent two different types of long-term memory [2][12]. Episodic memory represents memory of events and temporal-spatial relations among these events. This memory stores information in a serial form and allow us to reconstruct a specific experience with perceptible attributes. On the other hand, semantic memory is organized knowledge of facts, concepts and skills constructed by registering cognitive referents of input data. Perceptible attributes derived from episodic memory contributes to construct semantic memory. In regard to the structure of memory, this concept will be applied to explain the cognitive process that participants have performed.

In the following sections, a detailed description of experimental methods and the data analysis framework is presented. Results of previous research were extensively applied to construct a coding scheme and semantic maps for data analysis. In the last two sections, results and interpretation are presented in terms of implication for prior knowledge in design expertise and creativity.

2. Idea generation session with a think aloud method

A design task was given to six master students in the industrial design field. Half of them were male, and the other half were female. In this paper, three female participants are indicated as *F1*, *F2*, *F3*, and three male participants are as *M1*, *M2*, and *M3*. They participated in the experiment separately, but followed the same procedure and the setting as described below.

2.1 Experimental setting

The experiment was conducted in a closed room equipped with a desk, chairs and a video recording device to record the participants' hand movement, sketches, and the whole verbal data. A3 papers, pencils, pens and markers were provided for the participants' use. The overall setting of the experimental room is illustrated in Figure 1.

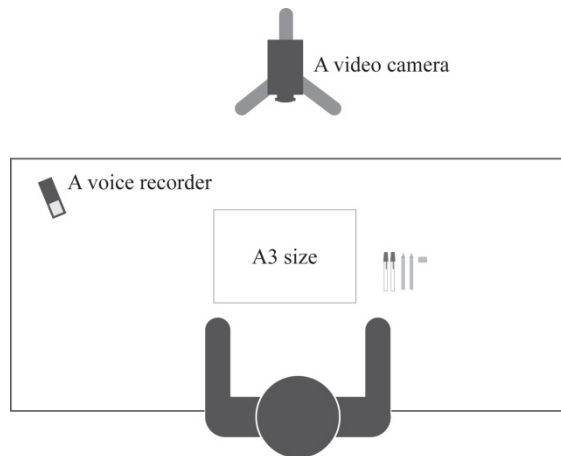


Figure 1. Experimental setting

2.2 Experimental procedure

1) Introduction : approximately 20min

The purpose and the procedure of this experiment were explained with a written document. A brief explanation about the think aloud method was also included in the document. The explanation about the methods, and their implementation referred to the think aloud method guide book [11]. After participants finished reading, a short think aloud exercise was performed. Participants were asked to generate three ideas to improve the given product based on the product description on the sheet. While doing this, participants used the think aloud method. Through this warming-up exercise, the researcher gave comments and corrected participants' faulty behaviours such as long silences and frequent use of meaningless fillers without verbalizing internal thoughts. This exercise helped participants to be accustomed to the think aloud method before entering the main experiment.

2) Idea generation session with a think-aloud method : 1hr 30min

Design Brief:

Design a folding chair. Please generate design concepts for this task and while you do so, try to say everything that you think or do in designing.

A design brief to design a folding chair was given to six participants as above in a written form. The researcher and participants had a short Q&A session before starting the design task. During the Q&A session, participants resolved their doubt related to the design problem, the range of tasks the participant would have to do, and so on.

During the session, there was no interaction between the researcher and the participant. Exceptionally, the researcher reminded participants to keep talking when they had not spoken for more than 10~15 second. Participants were not allowed to use additional external sources to facilitate idea generation, since this experiment was delivered to investigate how people utilize their memorized experiences.

3) In-depth interview after the idea generation session : approximately 30min

After the idea generation session, an in-depth interview was delivered with participants about their ideas and internal thinking process. Following questions were asked in a semi-structurized manner, and the drawings that participants made were reviewed together.

- Please explain each idea briefly in time order.
- What motivates or triggers these ideas? Instead of explaining the rationale or design concept, please explain about the starting point of ideas.
- If there was a specific experience or memory that you utilized to generate any idea, please explain it in detail.
- When the design direction changed or the topic switched from this to that, was there a special reason that you moved to that?

The whole verbal data generated in the interview session was also recorded. Through the in-depth interview, the researcher obtained more detailed description of participants' cognitive processes which were not fully described in the think aloud sessions.

3. Constructing semantic maps of cognitive idea generation processes

3.1 Transcribing

During experiments, three different types of data were obtained.

- Verbal data generated by a participant solely through a think aloud method during an idea generation session
- Visual data generated by a participants during an idea generation session
- Verbal data generated by both a participant and a researcher during an in-depth interview session.

Because the verbal data of the think aloud method was the primary source of analysis, the data was fully transcribed. The other two data sets were utilized complementarily to understand the whole cognitive process of participants in the analysis procedure.

3.2 Identifying three types of elements

All data was reviewed comprehensively with the background knowledge of previous researches related to precedents and design processes. While doing so, it was discovered that three different types of elements were utilized during the idea generation process. Based on the following definitions, these three types were identified depending on their characteristics and roles in the idea generation process.

1) Ideas

A discrete idea was defined as a design concept which satisfied the design brief, and was different either

aesthetically or functionally from others. Unlike other elements, ideas were articulated both verbally and visually. Also most of the participants showed similar behaviours of numbering each idea by themselves when they finished articulating an idea. Hence discrete ideas were easily identified in the design process. During the idea generation processes of participants, both sub-solutions and over-all solutions were found depending on participants' level of work detail [1]. In this research, 'ideas' mean over-all solutions which satisfy general requirements of the design brief.

2) Precedents

While creating ideas and developing them, participants referred to various artifacts and contexts. These artifacts and contexts were categorized as 'precedents' because they were recalled from participants' memory of prior knowledge and experienced. In this research, the term 'precedents' embraces comprehensive prior knowledge and experience regardless of its relationship with design. This definition is comparable to the meaning of precedents exploited by previous researchers. However, precedents without contextual foundation were not counted as precedents since they played a different role in the idea generation process. Instead of it, they categorized as another elements which are going to be explained later.

Depending on types of memory, two different types of precedents were retrieved and utilized. A first, named 'episodic precedents', was highly related to episodic memory which was usually retrieved in an artifacts or a single event. For instance, participant *F1* retrieved a product designed by her colleague with specific memory of its features.

"There was a product in our graduation show, uh, folding mat reminded me, it was designed by my friends and it looks like..."

The other type of precedents was recalled from semantic memory in order to construct a context or an environment for new ideas. These 'semantic precedents' were much more abstract and generalized compare to episodic precedents. It seemed participants had typological prototypes of precedents and exploited them to generate solutions as Oxman (1994) argued [9]. The following transcription showed how participant *M1* retrieved typified information and utilized it to assist his idea generation process.

"A chair means... A chair can be defined something with a backrest, a seat pad, and legs.. Among existing chairs, for example, a Beanbag is something a backrest, a seat pad and legs were integrated all together. But others, each component are distinctive and separated. So ... two different directions are possible..."

Participants *M1* was reminded of a prototype of chair from his semantic memory, and made a classification of prototypes using both episodic and semantic memory. Then he decided on a design direction based on his classification.

3) Interpreters

There was another type of element which didn't belong to either ideas or precedents, but performed an important role in the idea generation process. They were categorized as 'interpreters'. Items in this category were too abstracted and generalized to find relationship with episodic memory. Some episodic memory triggered these interpreters, but the interpreters themselves are relatively independent from contexts or domains. Due to their context-free properties, interpreters encouraged participants to expand the meaning of the design brief.

For example, most of the participants interpreted the task to design a 'folding' chair as a task to design a 'portable' chair. Some participants interpreted the meaning of folding as 'stackable', whereas other participant *M2*

interpreted it as ‘transformable’. Through these interpretations, new meanings of the design brief were produced by participants, and every new meaning expanded the cognitive ground to generate ideas. The process of generating and utilizing interpreters is similar to ‘goal propagation’ that Oxman (1990) described as phenomenon of the redefinition of goals while reflecting generalized precedents of designers [9].

3.3 Identifying chunks of a thinking flow

In order to break down the whole cognitive process into smaller chunks, thinking flows of participants were examined sequentially. When the thinking flow lost its continuity, it was regarded as a start of a new chunk. For example, the introduction of a new theme or a topic was one of the indicators which implied initiation of a new chunk. Whenever participants went back to the design brief to find a point of departure, it was also considered as the beginning of a new chunk.

In most cases, a chunk was concluded when participants formulated an idea with elements included in a chunk. Sometimes, however, participants moved to other issues without any relevant conclusion of the current topic. In this case, the beginning of a new chunk was regarded as the end of the previous chunk. Each chunk was considered as discrete, however, this does not mean that each chunk was totally independent. Several chunks are interconnected by sharing one or two elements.

3.4 Constructing a semantic map

Individual semantic maps were constructed for each participant in order to visualize their cognitive process. ‘Folding chair’, the main keyword of the design brief, was located in the center of each map, and three types of elements – ideas, precedents and interpreters – constructed relationships as participants described their cognitive process. Beginning elements of each chunk were connected to the center, and directional arrows were used to connect elements indicating the sequential order. All arrows were numbered in order of the thinking process. A part of a full semantic map is presented in Figure 2.

Although most of the chunks were directly connected to the design brief, certain chunks linked to other chunks consecutively because the last element of a chunk also behaved as a beginning element of next. Figure 3 shows abstracted versions of six semantic maps which highlight the chunks of a thinking flow.

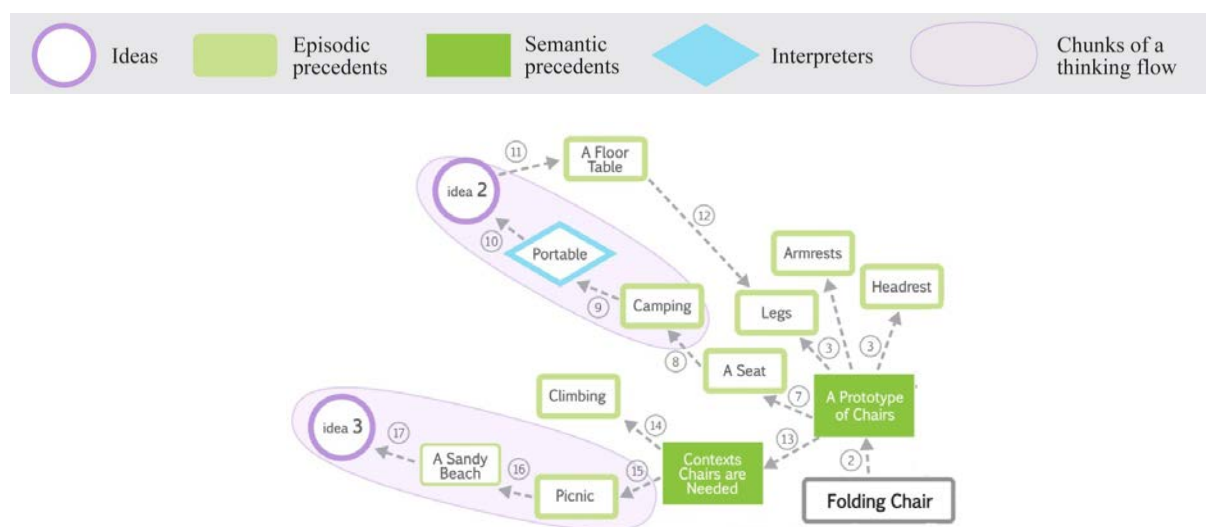


Figure 2. A part of semantic map of participant *M3*

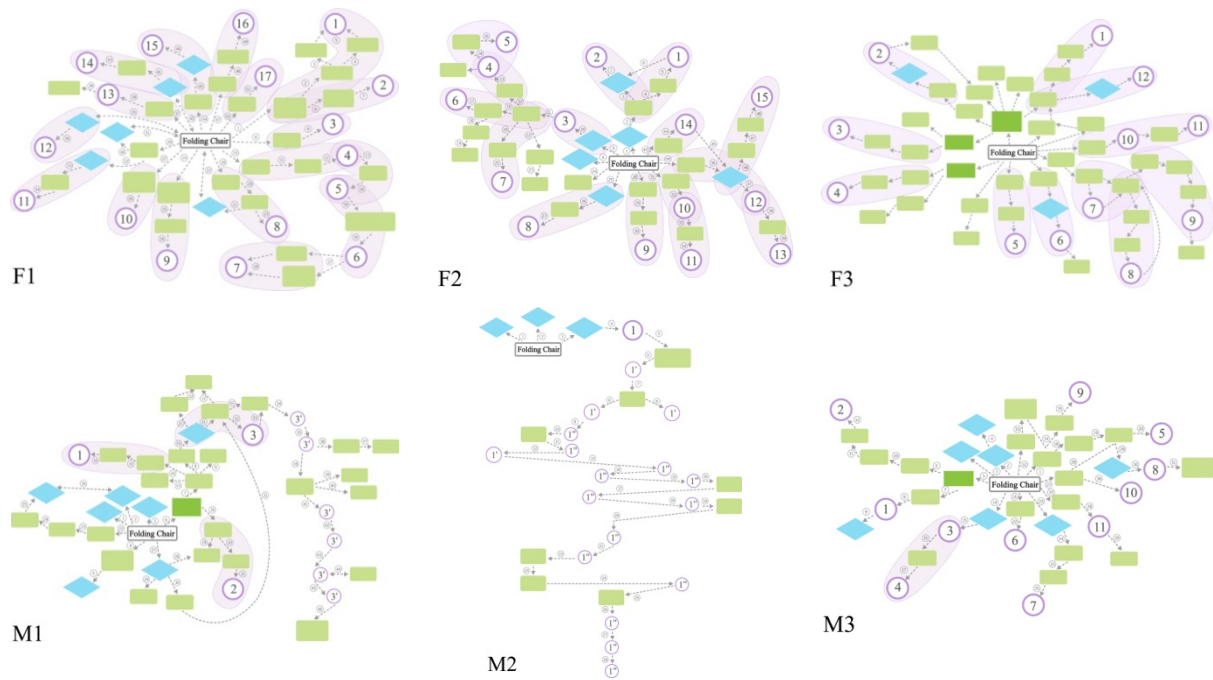


Figure 3. Abstract semantic maps of six participants

4. New findings of designer's idea generation process

4.1 Two types of thinking style

Table 1 shows the frequency of three types of elements – ideas, precedents and interpreters – as they appeared in each semantic network. As the table illustrated, six participants identically showed a tendency to utilize episodic precedents more than semantic precedents. Half of participants retrieved none of the precedents in the semantic type. This result matched with the argument of previous research that designers tend to rely more on experiential and episodic knowledge than theoretical and semantic knowledge [6]. It also supported the finding that episodic memory plays an important role in the design process [12].

Table 1. Number of three types of elements used in each semantic map

	Number of			
	Ideas	Precedents		Interpreters
		Episodic	Semantic	
F1	17	26	0	6
F2	15	23	0	6
F3	12	35	3	3
M1	3	26	1	7
M2	1	8	0	3
M3	11	18	1	7
TOTAL	59	136	5	32

Even though all six participants shared a similar pattern of retrieving more semantic precedents, it seems two different types of thinking styles exist from the perspective of idea generation. As shown in the column 'Number

of Ideas' in Table 1, participant M1 and M2 generated fewer ideas compare to the other four participants. Participant M2 even utilized remarkably fewer numbers of precedents than the others. In addition to numeric data, the shape of semantic maps also implies the existence of two different style of idea generation.

1) Divergent semantic map

Semantic maps of participant *F1*, *F2*, *F3* and *M2* are radial shapes which stretch toward the outside of the map. Participants generated relatively many ideas considering various contexts and users, though all ideas remained in a conceptual stage without details.

2) Hierarchical semantic map

Participant M2 showed an extreme case of hierarchical process, which develops detailed features of the product one by one and more concretely. The semantic map looks like a root of a tree which digs into the ground. During the whole design process, a limited number of contexts and users were considered and a few product concepts were generated.

Figure 3 shows three semantic maps which represent two thinking styles and mixture of them. According to the numeric data and the shape of the semantic map, the process of participant M1 seems to be a mixture of a divergent process and a hierarchical process. His think aloud data also supports the notion of a cognitive process was moved from divergent thinking to hierarchical process.

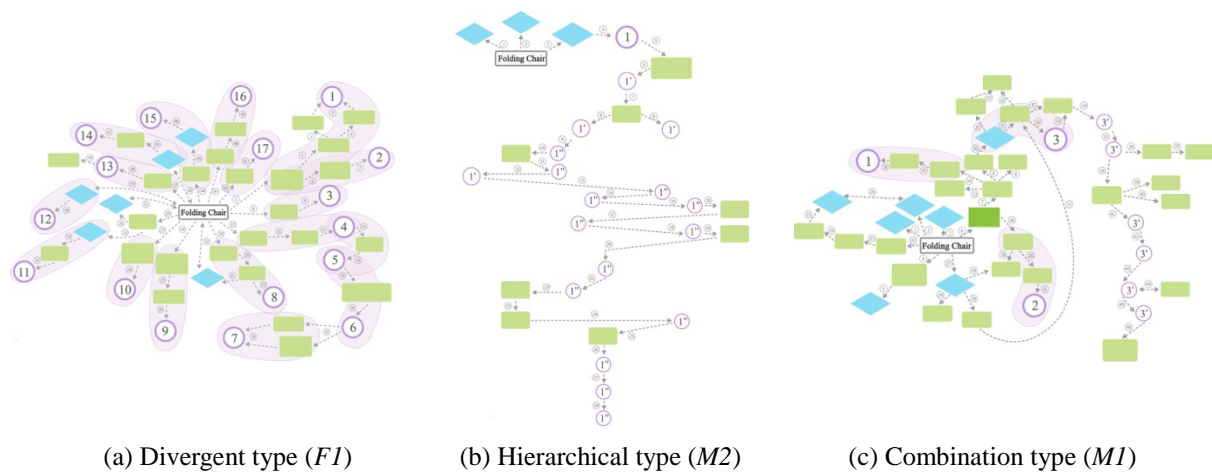


Figure 3. Semantic maps of the divergent process, hierarchical process and a combination of both.

Both thinking styles suggested meaningful information to investigate more, however, further analysis was done only with data from the four participants who showed the divergent thinking processes. It was judged that a divergent thinking process is more relevant to this research, because the main interest of this study is utilization of prior knowledge and experience in terms of creativity and expertise development.

Although the data of participant *M1* and *M2* were not examined further, an issue for future studies was proposed based on cognitive behaviour revealed by this level of analysis. Two participants showed similar patterns which support the concept of 'dominant influence' which was suggested by Peter Lowe based on his research about design activities in architectural design [8]. Lowe argued that even though the exploratory approach of designers – testing and evaluating possible alternatives one by one – looks typical, designers often focus on a particular solution concept because of a dominant influence exerted by initial design ideas.

For instance, participant *M1* explored several contexts which required a new folding chair. After this

exploration, however, he went back to the subway context that he had generated at the beginning stage of the design process. Only two design concepts were generated to test other contexts. After he had decided a context, he focused on developing a detailed design concept without backtracking.

Participant *M2* shows a more blinkered approach. Without generating other concepts, he started to develop his first idea gradually until it achieves a certain level of detail. Even during the development process, he considered a limited range of alternatives to materialize his concept.

Considering the number of generated ideas, these two participants are less divergent than the other four participants regardless of the level of detail of each idea. It is hard to conclude which ideas are more successful between the two thinking styles. In terms of creativity, however, there has been much research which supports the principle of a relationship between the ability of divergent thinking and a creative problem-solving process [13]. To facilitate a creative design process, considering ways to minimize the effect of a dominant influence is a direction for further studies.

4.2 Operational capacity to formulate ideas

Although lots of precedents help designers to generate possible solutions for the design problem, there is no precedent which can provide a perfect or exact answer. Precedents simply aid designers to create unique answers while exploiting and referring to them. Then, how designers produce novel concepts utilizing precedents? Lawson (2004) described this process as making a connection between design situations and precedents in episodic memory [6]. Cross (1997) also explained the idea generation process as bridging of a problem and its solution [1]. Oxman (1990) suggested the concept of match and three types of memory-based reasoning which explained how designers selectively retrieve precedents and create solutions [9].

Cognitive behaviours revealed in this study support the result of previous researches. In addition to this, a pattern was discovered related to the utilization of precedents. Table 2 shows how many elements were utilized to generate an idea. In the cases of participants *M1* and *M2*, they also displayed the same pattern as other participants though their data were not analyzed. Interestingly, participants didn't utilize elements exceeding three when they generated an idea. The exception to this was only one case with four elements. The number of elements used was same or less than three, and the average number of utilized elements was distributed around two.

Table 2. Number of elements used to generate each idea

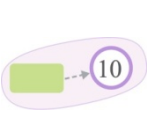
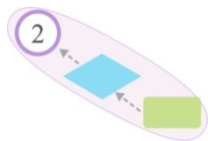

	Total number of ideas	Number of ideas generated with				Average number of elements used to generate an idea
		1 element	2 elements	3 elements	4 elements	
F1	17	5	11	1	0	1.70
F2	15	4	10	1	0	1.80
F3	12	2	6	4	0	2.17
M3	11	6	1	3	1	1.91
M1	3	0	3	0	0	2.00
M2	1	1	0	0	0	1.00
TOTAL	59	18	31	9	1	1.88

According to this data, it seems people have a limited 'operational capacity' to retrieve and utilize precedents while constructing a meaningful relationship with design problems. In the idea generation process, prior

knowledge and experience may be compared to numerous ingredients in the designers' memory pool. Designers selectively choose relevant ingredients and bring them onto working memory. In order to formulate an idea, designers create a new relationship between ingredients, and the newly created relationship is stored in working memory as part of an idea. Due to the limited working memory, however, designers cannot handle all the information related to each ingredient and their relationships at once.

Table 3 illustrates the number of items that working memory holds during generating an idea in a chunk of a thinking flow. In the case of idea generated with one element, working memory holds three items at once. In cases of two and three elements, it may hold five and seven items respectively. As more elements are added to a chunk, the working memory should operate more information at the same time, and utilize them to create an idea.

Table 3. Number of items that working memory should hold to generate an idea

Part of a semantic map (participant <i>F3</i>)			
Number of elements and ideas	2	3	4
Number of relationship	1	2	3
Total number of items to be operated in working memory	3	5	7

This concept is similar to Miller's magic number seven, which means the number of objects or chunks humans can hold in working memory is 7 ± 2 . They indeed share the same concept that working memory has limitation, however, this research shows a more dynamic aspect to the cognitive processes operating elements in the designers' memory. These results propose further studies related to expertise and creativity. First, the capacity of utilizing precedents may increase as expertise develops. Because this experiment was delivered by master students in the industrial design field, the expertise of participants is expected to have matured more than undergraduates, though they are not yet experienced enough to represent experts in the design field. To understand the relationship between operational capacity and expertise, further experiments are required with designers who have professional experience.

In this experiment, the quality of generated ideas was not judged. In reality, it is very difficult to judge which idea is better in terms of creativity. In spite of these difficulties, it will be valuable to explore the relationship between operational capacity and creativity of outcomes. If the ideas with more elements are creative, constructing more relationships with more precedents can be suggested as a methodological way to facilitate creative idea generation.

4.3 Idea triggers another idea

As mentioned before, certain elements were shared by two chunks. These were utilized in two different idea generation processes. Similarly, there were several cases that the last element of a chunk served as the beginning elements of a new chunk when two chunks are linked successively.

As shown in Table 5, there were a total of 14 cases where one element was shared by two chunks. Among them, half were ideas and almost the other half were precedents. It looks like both ideas and precedents were

utilized repetitively with a similar frequency. However considering the ratio of shared elements out of the total elements, ideas and precedents were differentiated. In the case of ideas, seven ideas were shared by two chunks among 55 ideas. In contrast, six precedents were utilized by two chunks among 106 precedents. The percentage of shared ideas out of total ideas was 12.7% and that of precedents was 5.7%. A great portion of idea elements were shared, suggesting ideas are actively performed in the idea generation process.

Table 5. Number of cases that an element shared by two chunks

	Total number of elements shared by two chunks	Frequency of sharing		
		Ideas	Precedents	Interpreters
F1	3	2	1	0
F2	6	3	2	1
F3	3	1	2	0
M3	2	1	1	0
TOTAL	14	7	6	1
Percentage of shared elements out of total elements		12.7%	5.7%	4.5%

This result implies a possibility that a kind of inertia exists in divergent thinking. Because an idea itself has a potential to trigger another ideas, designers seem to be able to produce more alternatives as they generate more ideas. It is hard to generalize this result since the sample size is too small. However, quantitatively successful process does not always mean producing high quality ideas. Although it is not sufficient to propose a concrete argument, the concept of inertia suggests possible studies to understand the divergent properties of design thinking.

5. Conclusion

In order to contribute to an understanding of the cognitive nature of the idea generation process, a design task was given to six master students to design a folding chair. Participants utilized the think aloud method while generating ideas. Through analyzing the data obtained during the idea generation sessions, three types of elements - ideas, precedents and interpreters - were identified. These were then used in the construction of semantic maps which represent the participants' cognitive process. These processes were then interpreted to identify the participants' cognitive behaviour both qualitatively and quantitatively with semantic maps.

This process of analysis resulted three major findings related to how designers generate ideas utilizing precedents. First, the thinking styles of participants were classified into two different types – one divergent, the other hierarchical. Depending on the style, the number of generated ideas and their level of detail was varied; a divergent style produced more ideas with rough concepts while a hierarchical style resulted in fewer ideas in greater detail. Secondly, it seems participants had similar operational capacities in their working memory to process information related to precedents and their relationship. Except in one case, all idea were generated with three or less than three elements. Several previous researches described idea generation process as constructing relationships between design problems and precedents. In this regards, the limited number of utilized elements

indicates the existence of the operational capacity of working memory which holds information of not only the elements but also the relationship among them. Finally, the potential ability of ideas' reproductivity was defined as inertia because an idea has a tendency to trigger another idea by itself.

Result of this research suggest a new way to visualize the cognitive process using a semantic map, and helps to identify relevant patterns related to the idea generation process. Especially the existence of operational capacity provides various implications related to expertise and productivity of the idea generation process.

For further studies, more intensive investigations related to the role of each element are required. Valuable insights related to the creative idea generation process can be obtained through understanding the role of precedents and interpreters in the idea generation process. Furthermore, it is expected to find meaningful implication related to expertise by conducting similar experiments with professional designers.

Acknowledgement

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