INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'07
28 - 31 AUGUST 2007, CITE DES SCIENCES ET DE L'INDUSTRIE, PARIS, FRANCE

VISUAL REASONING AND DESIGN PROCESSES

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ABSTRACT
Visual reasoning ability is a fundamental attribute in creative design process. This paper introduces a visual reasoning model composed of interaction of seeing, imagining and drawing that has eight components of perception, analysis, interpretation, generation, transformation, maintenance, internal representation and external representation. To confirm the eight components of visual reasoning model, we investigated visual reasoning processes of an expert designer and a student designer in a visual reasoning task through protocol analysis. As a result, we could trace a connected sequence in the visual reasoning model and found different connected sequences between the student and expert, which caused different results. Also, we observed the expert designer's visual reasoning process in a design task, which can be explained in the visual reasoning model. Active connected interaction of the eight components of the visual reasoning model is closely related to creative stages in design process.

Keywords: Visual Reasoning Model, Design Creativity, Missing View Problem, Protocol Analysis

1 INTRODUCTION

It is important to establish a concrete concept of design creativity and to find a distinct cognitive process for design problem solving in education of design creativity. At the Creative Design and Intelligent Tutoring Systems (CREDITS) research center, research work toward design creativity education is being conducted such that various underlying cognitive elements of design creativity are identified and then these design creativity elements can be enhanced through training methods reflecting individual learner's cognitive personal characteristics [5]. As a critical element of design creativity, visual reasoning capability has been identified [6], and an intelligent tutoring system has been developed for visual reasoning [24]. Also, various visual reasoning abilities were observed in devised visual reasoning tasks and were explained in a visual reasoning model [14]. In this paper we introduce a visual reasoning model which consists of eight components and we confirm it in a visual reasoning task through protocol analysis. As a result of protocol analysis, we can find how visual reasoning process facilitates design creativity.

2 VISUAL REASONING AND DESIGN CREATIVITY

2.1 Visual Reasoning

Basically reasoning can be defined as going beyond the information given [2]. In this aspect, [23] suggested that there are two ways in going beyond the information: one is to transform information according rules and the other is to make inferences or judgments from the information. In visual reasoning the given information can be regarded as visual information such as designer's sketch. To transform or infer from such information, observation and interpretation of visual information should be preceded. Also, retrieval of rules and usage of visual knowledge are necessary. At last, externalization is needed for confirmation of the results. These processes can be explained in iterative process of seeing, imagining, and drawing: imagining process to synthesize in mind, the drawing process to represent the synthesis results, and the seeing process to analyze the drawings [11]. The nature of design reasoning as the iterative process of seeing-moving-seeing has also been discussed in [16]. With the above intent, we define visual reasoning as an iterative process composed of visual analysis, visual synthesis and modelling so that these three would account for seeing, imagining and drawing, respectively.

2.2 Visual Reasoning and Design Creativity

A number of researchers have found a critical relation between visual reasoning and creative design, [10], [21], [17], [12]. There have been trials to prove complex interaction between external representation and cognition through protocol analysis using video and computer records of designers' sketching activity [10]. In their study they concluded sketch can facilitate visual reasoning in design. Through protocol analysis, [21] also verified that 'conceptual design process using sketches is a visual reasoning where sketch are the media amongst perceptual and conceptual knowledge, enabling the creative design process to happen.' In addition, [17] supported emergent shape as a phenomenon of visual reasoning plays a significant role in the creative design process and they made an effort to develop the computational models capable of representing emergent shapes. Through an empirical study of designers' behaviour in the graphical adaptation of a design solution, [12] suggested that visual reasoning is a keystone of the creative process which can result in designs of unexpected diversity and novelty. From preceding studies we can convince visual reasoning is essentially related to design creativity.

2.3 Visual Reasoning tasks and Design Creativity

There have been different trials to reveal the visual reasoning abilities in experimental studies, [9], [20], [6]. [9] suggested problems of seeing shapes in design, which can be related to visual reasoning issue and devised experimental task to discover sub-shapes. Through his experiment, he found that experts have lower thresholds of recognizing activation so that they can discover more implicit sub-shapes than novices. Also, [19] proved that their Constructive Perception (CP) task was valuable in comparing visual reasoning ability between experts and novices. In CP task they found that expert designers generated more interpretations about ambiguous pictures than novice designers. In addition, [6] proved that in visual reasoning ability task, so-called Missing View problem (MV) task, there were different performances between engineering, industrial design, and psychology students. Industrial design students who were assumed to be most creative among groups obtained the highest scores in MV task. Besides, scores of MV task was correlated with design creativity scores of students. In [14], two more visual reasoning tasks were devised and performed by first and second grade students. One was a Perspective-Plan view Matching (PPM) task which enables us to measure ability in extraction of predicate in architectural space, imagery transformation, and image maintenance. Another was a Emergent Shape (ES) task which make it possible to test an ability to interpret visual information and infer unexpected shapes. From their results that second grade students had better performances than first grade students in visual reasoning tasks and MV task had correlation with PPM and ES task and ES task was correlated with design task.

2.4 Purpose of Study

From results of these visual reasoning tasks, we can conclude the visual reasoning ability can be measured. However, it is not enough that the scores of visual reasoning tasks explain the visual reasoning processes in creative design processes. Therefore, we laid a visual reasoning model through which we tried to observe how the visual reasoning processes were going on, and how the visual reasoning abilities affected design process. In this paper we research visual reasoning process in our model with purposes as following:

- to Confirm that eight components of visual reasoning process are meaningful
- to Trace a connected sequence in visual reasoning model for a visual reasoning task
- to Find which components would correspond with visual reasoning abilities
- to Compare visual reasoning process between an expert designer and a student
- to Find a critical visual reasoning process of an expert designer in a creative design process

Eeventually, this research makes it possible to find a deficient visual reasoning ability of individual for creative design education system. That is the reason why we have studied a creative design process.

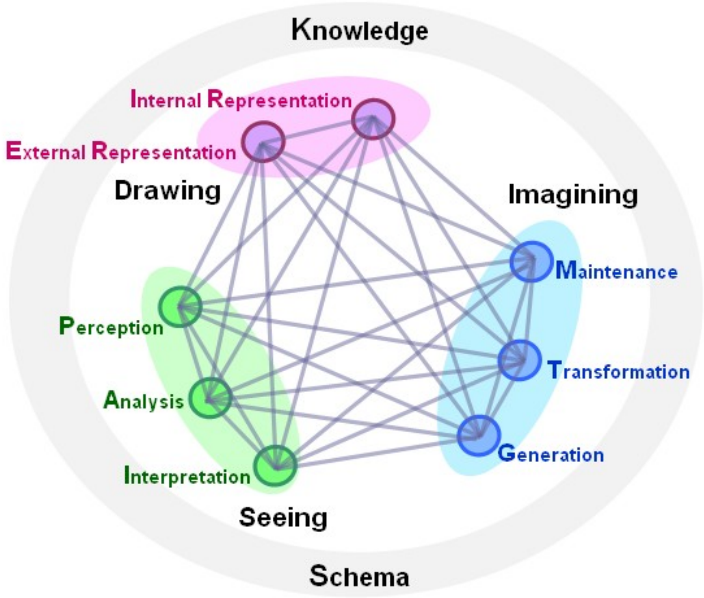


Figure 1. Visual reasoning model

3 VISUAL REASONING MODEL

3.1 Visual Reasoning Process

Visual reasoning process includes visual analysis, synthesis, and modelling process which can be viewed as seeing, imagining, and drawing process [11] as we defined visual reasoning. These processes occur in the interaction with perceptual and conceptual process. We classify whole process into eight components and arrange how each component is specifically consisted of. Through this visual reasoning model, characteristic of visual reasoning processes can be clearly examined. We can trace connected sequence of each designer. Then, we can discover specifically how different each designer's visual reasoning process is.

3.1.1 Seeing.

In seeing process, visual perception (P), analysis (A), and interpretation (I) occur. In *perception*, identification of primitives, combination of primitives, and recognition about the visual information occur. In *analysis*, observation about relations of primitives and exploration about predicates of the visual information occur. In *interpretation*, categorization and giving new meaning to the perceived objects occur with memory. This process brings about extraction of predicates as needed for new image generation and transformation.

3.1.2. Imagining.

Imagining process enables to synthesize using perceptual and conceptual information for new representation. Imagining process can be classified as generation (G), transformation (T), and maintenance (M). These three components were mentioned by [8], together with the fourth component of inspection to account for imagery process. In [4], generation and transformation were proved to be critical in creative design process. Image *generation* occurs with two ways: one is from perceptual input online through seeing process and the other one is from activated knowledge and schema stored in long term memory (LTM) [8]. Image *transformation* can be differentiated with two kinds: congruent transformation and pattern change transformation. [8] defined image transformation as limited meaning similar with physical perception such as mental rotation and image size change. We categorized this kind of transformation as congruent transformation. On the other hand, [13] suggested 'image pattern altering' process such as emergent shape. We categorized this kind of transformation as pattern change transformation. After the image transformation, image *maintenance* occurs for keeping the internal representation.

3.1.3 Drawing.

Drawing process enables representation through both ways to internalize and to externalize. In *internal representation* (IR), the transformed image is to be evaluated and confirmed. This process occurs in the interaction with imagining and seeing process. In addition, *external representation* (ER) serves as external memory, in which to leave ideas as visual tokens, so that they may be revisited later for inspection [18]. In the process of conversion from internal representation to external representation, generation of imagining process can occur as well. That is why drawing process is important in visual reasoning. Also, the drawing process enables to manipulate and transform the images. In this way sketch can facilitate visual reasoning.

3.1.4 Knowledge & Schema.

Knowledge (K) and schema (S) are engaged in the interaction with visual reasoning process. [15] suggested that empirical knowledge such as test information and image information affects the iterative process of framing, moving, and reflection. That is, retrieval of visual knowledge from LTM becomes a cue to match between visual input and visual memory for visual perception in seeing process. Also, by visual schema retrieved from LTM which becomes a rule for extraction of predicate, visual information can be reorganized in iteration process of seeing and imagining. These iterative processes make it possible to transform and modify the existing visual input in imagining process. [13] also suggested that it is essential to know how to transform and how to access schema of basic structure in reformulating images. In addition, order and pattern of drawing can cause different visual reasoning according to designer's drawing schema. The schema can play a critical role to link between conceptual and perceptual process in drawing process. As a result, diverse manipulation of images can be generated.

As we looked into visual reasoning process, seeing, imagining, and drawing process occur not independently but interactively with knowledge and schema: in all visual reasoning process, there exists interaction between perceptual and conceptual knowledge. [13] emphasized that perception and conception process can provide a working basis for conceptualizing visual cognition in design. [1] also mentioned that a dependent relationship between perception and visual cognition. Therefore, visual reasoning is linking process between perceptual and conceptual knowledge [22]. This is our visual reasoning process model and it is illustrated in Figure 1.

3.2 Coding Scheme for Visual Reasoning Model

For confirming and tracing the eight components of visual reasoning model, we need a systematic and specific coding scheme. Therefore, we consider to use [18]'s coding scheme. In their study coding scheme was confirmed for design action defined systematically. Through protocol analysis with this coding scheme, they could find roles of design sketches. Also, their coding scheme was used for imagery process analysis in design process [4]. As a result, they found different imagery process between experts and novices. Now that these studies were about cognitive and perceptive process in design, we judge that this coding scheme can be appropriate to our research about visual reasoning process.

In [18]'s study, they categorized four kinds of design action such as physical, perceptual, functional, and conceptual actions, and then fractionize into minimum coding scheme about each category. *Physical actions* consist of making a depiction, moving, and looking actions. *Perception actions* consist of 'attend to visual features of elements' such as shapes, sizes, and textures,'attend to spatial relations among elements' such as proximity, alignment, and intersection, and 'organise or compare elements' such as grouping, similarity, and contrast. *Functional actions* consist of 'explore other issues of interactions between artefacts and people/nature' and 'consider psychological reactions of people' such as fascination, motivation, cheerfulness. *Conceptual actions* consist of 'make preferential and aesthetic evaluations' such as like-dislike, good-bad, and beautiful-ugly, 'set up goals', and 'retrieve knowledge.' With these coding schemes we categorize them properly into eight components in visual reasoning model. Table 1, 2, and 3 shows each coding scheme corresponded into the component. If there is not a proper coding scheme corresponded into the component, we insert new

Table 1. Coding Scheme for Seeing process

Component	Definition of Component	Coding Scheme	Explanation of Coding by Suwa et al. (1998)
Perception	Identification of primitives, combination of primitives, & recognition about the visual information	Pfn	Attend to the feature of a new depiction
		L	Look at a previous depiction
Analysis	Observation about relations of primitives	Pfnp	Attend to the feature of a new relation or Psg
		Prnp	Create or attend to a new relation between a new depiction and an existing one
		Prn	Create or attend to a new relation between two new depictions or Psg
		Pcf	Continually attend to a feature
		Pcr	Continually attend to a relation
		Pcsg	Continually attend to a space as ground
	Exploration about predicates of visual information	Ae	
Interpretation	Categorization, giving new meaning to the perceived objects	Psg	Discover a space as ground
		Pfp	Discover a new feature of an existing depiction, of Pcsg or of Prsg
		Prp	Discover a spatial or organizational relation

coding scheme in which there is no comment in 'explanation of coding by [18]' column of Table 1,2, or 3. We explain this re-categorization in next three sections.

3.2.1 Seeing.

We use most coding schemes of perceptual actions and 'looking' coding scheme of physical action for seeing process in our visual reasoning model. As [3] suggested, extraction of predicates is important process in visual reasoning process. It is because interpretation about visual information can depend on which predicate is extracted. Also, the interpretation can affect transformation in imagining process. However, there is no coding scheme about this process in [18] so that we added 'Ae' coding scheme which represent extraction of predicates from visual information. Table 1 shows coding scheme for seeing process.

3.2.2. Imagining.

Imagining is very important as synthesis process in visual reasoning. We use coding schemes of perceptual actions such as 'Prf,' 'Prr,'and 'Prsg' for generation. Especially, transformation process is

Table 2. Coding Scheme for Imagining process

Component	Definition of Component	Coding Scheme	Explanation of Coding by Suwa et al. (1998)
Generation	Generation from perceptual input online Generation from activated visual information stored in long term memory (LTM)	Prf	Remember a feature of a depiction
		Prr	Remember a spatial or organizational relation
		Prsg	Remember a space as ground
		Fnp	Think of a function independently of depictions
		Fr	Remember a function
		Frp	Remember a function independently of depictions
Transformation	Congruent transformation	Tc	
	2D <-> 3D transformation	Td	
	pattern change transformation	Tp	
		Fn	Associate a new depiction, feature or relation with a new function
		Fre-i	Re-interpretation
Maintenance	Thinking about the generated image or idea continually	M	
		Fcp	Continually think of a function independently of depictions
		Fc	Continually think of a function

Table 3. Coding Scheme for Drawing process

Component	Definition of Component	Coding Scheme	Explanation of Coding by Suwa et al. (1998)
Internal **R**epresentation	Confirmation about the transformed image or idea	IR	
External **R**epresentation	Serving as an external memory	Drf	Revise the shape, size or texture of a depiction
		De	
		Dc	Create a new depiction
		Dts	Trace over a depiction on the same sheet of paper
		Dtd	Trace over a depiction on a new sheet of paper
		Dsy	Depict a symbol that represents a relation
		Dwo	Write sentences or words that express ideas
		Pipsr	Implement a previously mentioned relation by giving new depictions or feature
		Fi	Implement a previously explored function by creating a new depiction, feature or relation

critical; however, [18] has no coding scheme about transformation. As we mentioned above, transformation can be classified into congruent and pattern change transformation so we added coding scheme according to kinds of transformation. In addition, coding scheme about function in design process is included in 'Function Action' in [18]. Among the coding scheme about function, we classified coding scheme of idea generation about function into generation category, and classified coding scheme of association and re-interpretation about function into transformation. Also, we added 'M' coding scheme for maintenance process which is for keeping generated or transformed image and idea. Table 2 shows coding scheme for imagining process.

3.1.3 Drawing.

We use coding schemes of drawing actions of [18] for external representation in our visual reasoning model. Now that there is no coding scheme for internal representation in [18], we added 'IR' coding scheme for that. This process is important for evaluation and confirmation of generated or transformed image and idea. In addition, we categorize 'Pipsr' and 'Fi' into external representation. Because this coding scheme is for implement a previously mentioned relation or explored function by creating a new depiction, feature or relation, we judge this process is modelling by externalization. Last, we added 'De' coding scheme for erasing. Table 3 shows coding scheme for drawing process.

4 CASE STUDIES

We studied two kinds of cases for protocol analysis of visual reasoning process. The first one is consisted of MV task which has been acknowledged as a representative visual reasoning task [7], [6], and [14]. Through case study 1, we can find differences of visual reasoning processes between expert designer and student, and also confirm meaningfulness of eight components in visual reasoning model. The second one is consisted of design task. In case study 2, we analyze expert designer's visual reasoning process. This is for knowing how visual reasoning process facilitates design creativity. We use Interact program for protocol analysis. The program makes it possible to segment even frame, which is absolutely necessary for visual reasoning process analysis. We segmented protocol by a meaningful sentence or word and externalized feature.

4.1 Case Study 1: Missing View Problem Task

4.1.1 Procedure

An expert designer who has worked for 7 years in industrial design and a student of engineering participated in MV task. In MV task according to [6]'s method, much explanation on how to solve the problems is not provided, but a very general introduction on perspective projection and orthographic projections. Participants are required to construct a valid 3-D solid object visually by analyzing two

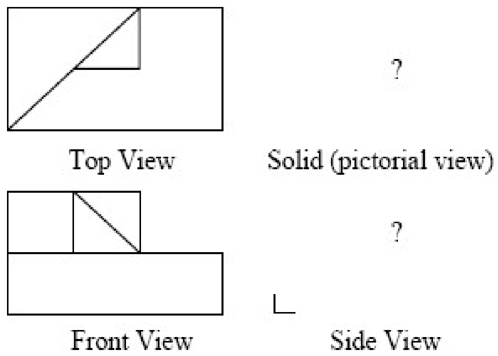


Figure 2 MV task as an example

2-D orthographic projections and to form the missing view orthographic projection. They should find solution satisfying these geometric constraints given with two orthographic views. Two missing view problems are given. The problems are presented in order of a degree of difficulty. Orthographic projections of top and front view are given so that both pictorial and missing view should be sketched by participants. MV task was conducted on computer screen using Alias sketch program with Camtasia which records all progress on the computer screen. In addition, the designers were asked to think aloud all design processes during solving problem. Also, all experiment process was videotaped. An example of missing view problem is shown in Figure 2.

4.1.2 Results and Discussion

From protocol analysis, we could find eight components were connected meaningfully. An example of protocol analysis is shown in Table 4. The graph of Figure 3 shows interaction between components of visual reasoning model by coding according to time sequence. Under the graph, we present connected sequences of visual reasoning process during about 2 minutes in our visual reasoning model. This part was decided to be important for visual reasoning solution. Because it is hard to recognize the sequence if we expressed all sequences in one model, we expressed them in three. (1), (2), and (3) under the graph indicate the part where the connected sequences are expressed in each model figure. In Table 4 we present number in the first column which is same as the number expressed for order of sequence in Figure 3. In the second column we present connected sequence of components of visual reasoning model, which is helpful for tracing the arrows of Figure 3. We present protocol of expert designer in the third column and we explain designer’s behaviour in the fourth column. In the last column, we present coding scheme.

4.1.2.1 Visual reasoning abilities required in MV task

As you can see the connected sequence in the visual reasoning model, the eight components are connected meaningfully. Through protocol analysis, we can find the visual reasoning abilities which are required in MV task as following.

- Extracting of predicates from problem for searching linking part of projections from different two views through perception (P) and analysis (A)
- Generating alternative images (G)
- Inspecting generated images comparing with given sketches through perception (P) and analysis (A) in internal representation (IR)
- Transforming image (T) with repetitive analysis about sketches (A)
- Externalizing image through sketching (ER)
- Transforming structure from 2D to 3D or from 3D to 2D (T)
- Comparing with given sketches and potential results perception through perception (P) and analysis (A)

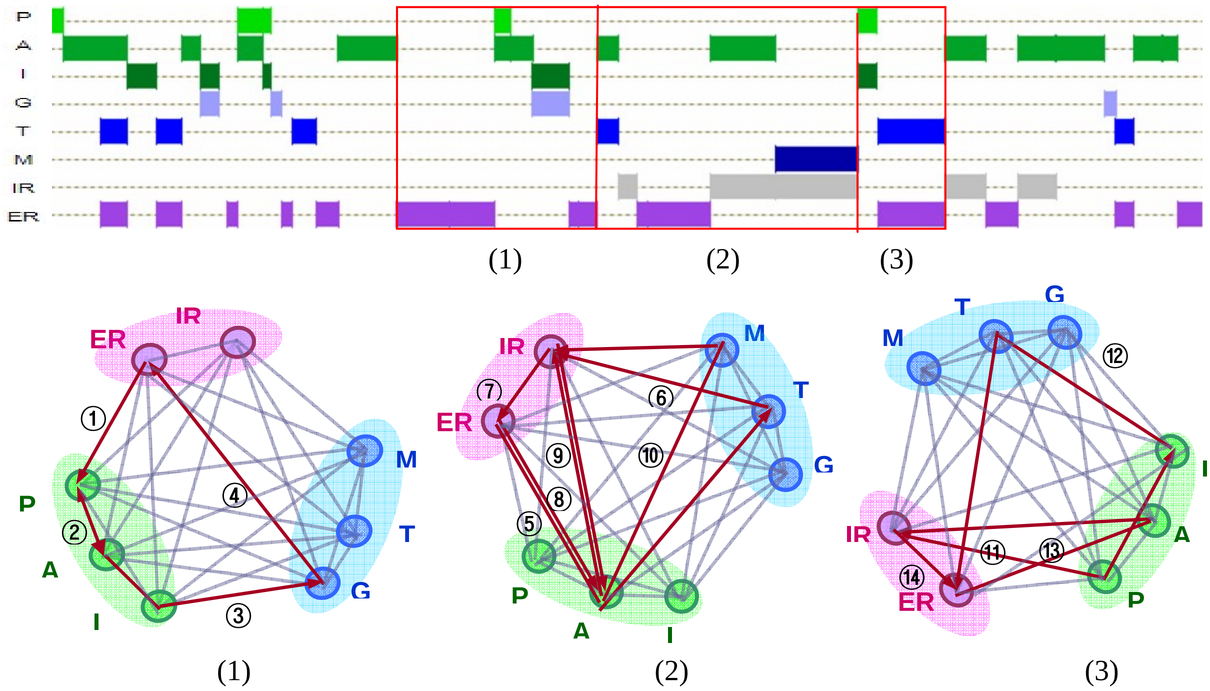
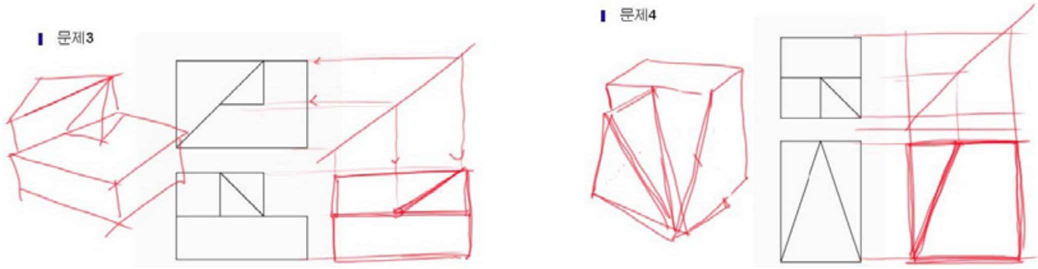


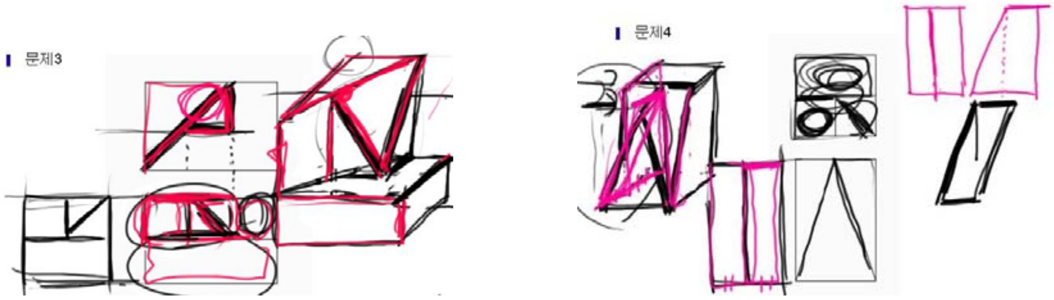
Figure 3 Results of Protocol Analysis of Expert Designer in MV 2

Table 4. A Part of Protocol Analysis of Expert Designer in MV 2

	Connected Sequence	Protocol	Explanation	Coding Scheme
①	ER→P		He drew extended line from top view and front view. We assume that because he could not find relation between top view and front view, he could not go to image generation so that he tried to externalize for finding solution.	Dc
②	P→ A	This line comes straightly. Here is the line.	He was thinking about relation of lines between sketch and top view	Pfn, Prnp
③	A→I→G	The line is here. Here… there is line from here to there…	Continually, he attended his own sketch with comparing front view and he interpreted lines of right view.	Prnp, Prp
④	G→ER		With generating image, he drew extended lines from sketch.	G, Dc
⑤	ER→A→T		He drew lines over his sketch and attended his sketch comparing front view.	Dts , Prnp
⑥	T→IR		We assume that he transformed image from 2D to 3D because he had drawn 2D sketch, and he would evaluate 3D sketch in next segment.	Td
⑦	IR→ER	If so, actually…	We assume that he confirmed the transformed image in internal representation because he would revise his sketch in next segment.	IR
⑧	ER→A	It does not exist. Here, this shape…	He erased the line which was wrong in his sketch.	De
⑨	A ↔ IR	……Right?	We assume that he evaluated generated image in internal representation because he mentioned "…right?"	Prnp, IR
⑩	A↔M↔ IR	…… Right.	We assume that he continually evaluated the image with maintaining the image.	Prnp, M, IR
⑪	IR→P→I	........Um......	He looked his sketch and right view alternatively and attended relation between top view and right view and found out wrong parts of 3D shape.	Prn, Pfp, Prp
⑫	I→T→ER	This line comes like this.	He transformed 2D to 3D and draw the 3D shape. Because he found solution from 2D he should revise his first 3D sketch.	Td, Dc
⑬	ER→A↔ IR	…. This face…If so, that's right.	He evaluated transformed image of 3D sketch with comparing 2D sketch.	Prnp, IR
⑭	IR→ER	Erase... This line is wrong.	He erased wrong line of 3D sketch. We assume that he externalized the internal representation which was in before segment.	De



(1) Solution of Expert Designer in MV task



(2) Solution of Student in MV task

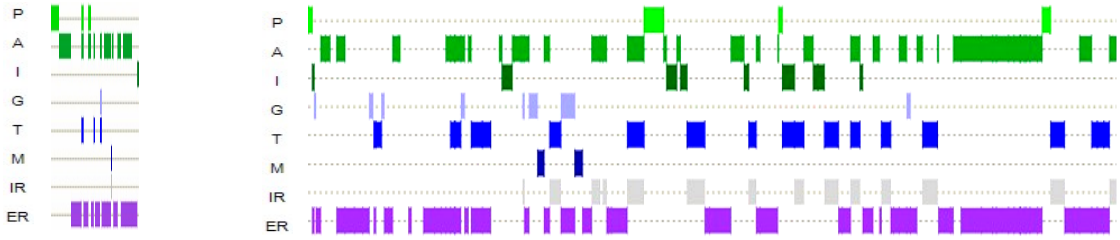
Figure 4 Solution of Expert Designer and Student in MV task

4.1.2.2 Reason why solvers had wrong solutions

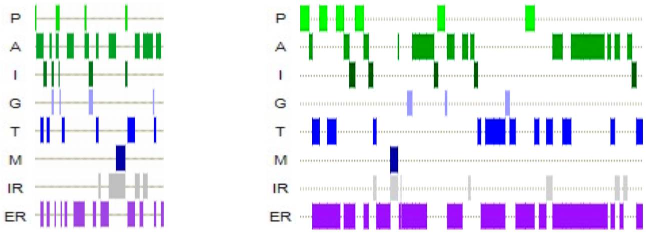
The result of MV task, the expert designer spent about 2 minutes in MV 1. He closed the answer but had wrong solution. In MV 2, the expert designer spent about 3 minutes. He reached right answer. Expert designer’s results are shown in Figure 4. The student spent about 20 minutes and had right solution about MV 1. In MV2 he spent about 9 minutes. He closed the answer but had wrong solution. Results of the student in MV task are shown in Figure 4. So, what is the reason the expert designer and student reached wrong answer even though both of them closed the right answer? From protocol analysis, commonly, they had wrong answers when they did not evaluate their solution enough. We can conclude from different duration of IR. We defined IR coding scheme specifically as time in which the solvers did not externalize and they confirmed about their solution. The duration of IR of the expert designer was different between right and wrong solution (45s Vs. 1s). From the fact that the expert designer solved MV 2 very quickly in 2 minutes, we assume he did not have enough time to evaluate about his solution. However, he had enough time to evaluate and revise his solution in MV 2. The point in which he confirmed about their solution made it possible for him to reach right answer. The student also made a similar mistake that he did not had enough confirmation in internal representation. The IR was different between right and wrong solution (17s Vs. 8s).

4.1.2.3 Differences between Expert Designer and Student in Visual Reasoning Process

First, we can find that the expert designer spent shorter time than the student as you can see in Figure 4. Actually, the graph of expert designer in MV 2 in Figure 5 is same as ‘Results of Protocol Analysis of Expert Designer in MV 2’ in Figure 4. We narrowed the graph for comparing other graphs according to duration of each problem solving process. Also, the expert’s iteration of visual reasoning process is much faster than student. The ability helps the expert designer to have faster performances. In addition, student’s sketch was not good enough for finding solution so that he was perplexed and then draw his sketch again and again. That is another reason he reached solution later. From the analysis we confirm that sketching facilitate visual reasoning. Furthermore, the student had relatively shorter duration of IR compared to the expert designer even though he spent more time than the expert designer. It could be the case that he externalized his analysis or evaluation mostly. From the analysis, we believe that the expert designer could internalize image better than the student. We suggest that expert designer can maintain and represent an internal shape easily because of diverse visual schema such as experience of projections. If the solver has affluent experience of projections and schema on how to transfer, it would be easy to construct and transform images.



(1) Expert Designer in MV 1 (Duration 1:54) and Student in MV 1 (Duration 20:02)



(2) Expert Designer in MV 2 (Duration 3:33) and Student in MV 2 (Duration 8:55)

Figure 5 Visual Reasoning Process of Expert Designer and Student in MV task

4.2 Case Study 2: Design Task

4.2.1 Procedure

The given design task was to design a family play tool usable in the park of apartment area. 60 minutes was given for solving the design problem using Alias sketch program in computer environment with Camtasia which records all progress on the computer screen. In addition, the designer was asked to think aloud all design processes during solving problem. Also, all experiment process was videotaped. Figure 6 shows designer's sketch which was generated in design task.

4.2.2 Results and Discussion

While design task was conducted during 60 minutes, we analyze an idea generation stage for about 8 minutes in which we judge that visual reasoning process occurs actively and contribute to a creative design solution. As you can see the graph by coding in time sequence in Figure 7, the eight components of visual reasoning model were interactively used. Especially, in the most interactive connection of the boxed portion in Figure 7, the creative idea came up. At first, the expert designer considered 'chair play' so that he started to sketch chair which should be easy to carry. During sketching the chair which can be shrunk for portability, he suddenly thought about a hoop idea after seeing the shrunk chair can be rolled. The idea was developed into dual-way play of a chair and hoop. In this way, the expert designer made a creative design with visual reasoning process. This supports our assertion that actively connected interaction among the eight components in visual reasoning brings out design creativity.

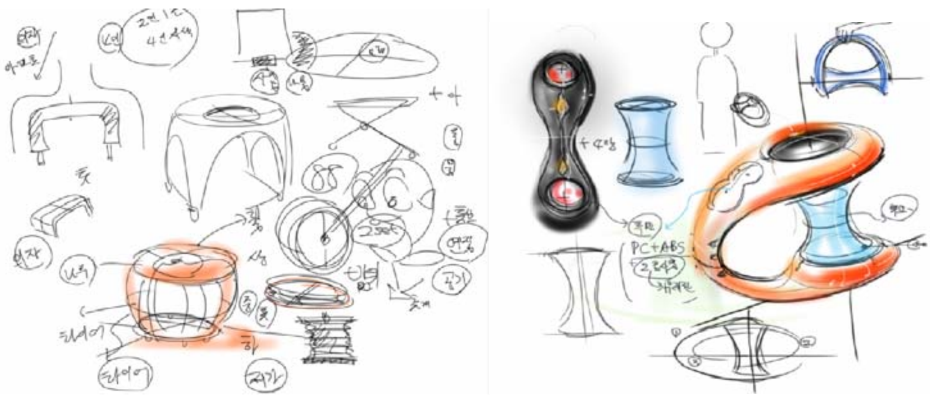


Figure 6 Concept design sketches

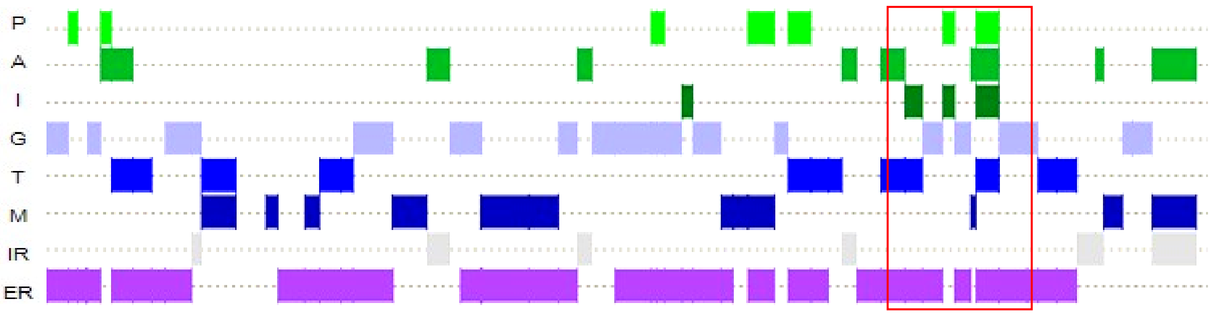


Figure 7 Result of Expert designer in Idea Generation of Design Process (Duration 8:23)

5 CONCULSION

According to preceding studies, visual reasoning is related to design creativity [10], [21], [17], [12]. Especially, it has been proved that visual reasoning ability of MV task is related to design creativity, [6], [14]. Therefore, in this study we tried to scrutinize visual reasoning process in MV task. For the analysis, we use a visual reasoning model composed of interaction of seeing, imagining and drawing that has eight components of perception, analysis, interpretation, generation, transformation, maintenance, internal representation and external representation. In the case study about an expert and a student designers' performance in MV task, we confirmed that eight components of visual reasoning process were actively connected. Through comparison of two designers' visual reasoning processes, we could find importance of good sketch, visual schema, and IR process. Especially, IR process which is defined as a process where the designer makes an internal representation for analysis is important for an exact solution. In addition, we confirm that eight components of visual reasoning process in design task were meaningful. The result of protocol analysis shows that the most actively connected sequence of visual reasoning components can bring creative idea. From those results, we confirm that connected relations of eight components are important. If we find more meaningful connected sequences in the visual reasoning model from expert designer's protocol data, we can find what is critical in design process. As visual reasoning process is an underlying cognitive process that has close relation with design process, student designers could be trained the reasoning process for design through well-structured visual reasoning exercises.

ACKNOWLEDGEMENTS

This research was supported by the Korean Ministry of Science and Foundation under the Creative Research Initiative program. Special thanks go to the expert and student who participated in the experiment.

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