IASDR07
INTERNATIONAL ASSOCIATION OF SOCIETIES OF DESIGN RESEARCH THE HONG KONG POLYTECHNIC UNIVERSITY 12TH TO 15TH NOVEMBER 2007

THE INFULENCES OF UNSTRUCTURED AMBIGUOUS FIGURES IN IDEATION AND INTERPRETATION

Winger Tseng

Industrial Design department, School of Art and Design, The Yunlin University of Science and Technology, Doulie, Taiwan, tsengws@yuntech.edu.tw

ABSTRACT:

This paper, mainly focusing on the visual ambiguous properties being produced by designers during ideation sketching, explores how the degree of ambiguous figures affects designers' idea and interpretation during design development, and investigates the difference between experts and novices. The majority of the conceptual sketches in early conceptual design stage are presented unstructured, vague, and incomplete contour properties, which contain ambiguous and multiple meaning. The study proposed that the conceptual sketches containing vague, incomplete, and ambiguous visual properties, might be the fundamental elements for design ideas to provoke unexpected discovery and new interpretation. The results showed that the different degrees of ambiguous sketches is significantly influenced the quantities of idea development of experts, but without any significant difference founded in novices. The higher the degree of ambiguous figures was viewed during design development, the more quantities of ideas had been created by experts; yet, novices produced more ideas in executing the lowest ambiguous figure task. The majority of design interpretation created by both experts and novices

were affected by the presented geometric contour of figures. Similarly, when viewing the highest degree of ambiguous figure tasks, experts produced more interpretations than when viewing the moderate and lowest ambiguous figure in tasks. In interpreting a new function or meaning simulated by geometric contour, experts produced significantly more quantities than novices. As a result, the higher degree of ambiguity in figures could make designing development keep flexibility and numerous categories of creativity, and consequently, it allows designers to retain further horizontal thinking transformation and interpretation, and to avoid premature problem solution and creative concept.

1. INTRODUCTION

This paper is mainly focus on the designers' sketching behaviour, especially during the early phase of product design development when visualising their creative concepts on paper, and special meanings on cognitive process. During the process of design, sketching or free-hand sketching is the most common instrument used by designers, particularly when conceiving their ideas in preliminary period of product design. Even the CAD or CAID (Computer Aided Design or Computer Aided Industrial Design) has already been developed for more than 20 years, paper and pencil are still one of the main tools for visualizing concepts. However, why should these impoverished symbols be so important to designers in the preliminary phase of design, and why should they be so irreplaceable, given the prevalence of CAD programs. Sketches must possess exceptional properties that make them indispensable to designers when creating design ideas.

Freehand sketching is widely utilized by designers that it serves not only as an external memory in which to place ideas for later inspection but also to provide visual cues for associating functional issues (Suwa and Tversky, 1997). Sketches, most importantly, serve as a physical setting in which functional thoughts are constructed on paper in a situated way. The particular visual characteristics of external symbols in sketches are ones that support and facilitate the kind of visual reasoning engaged in the early stages of design, as does the actual activity of sketching (Scrivener and Clark, 1993). This reasoning displays a regular shift between two modalities of argument, i.e., depictive and descriptive aspects of candidate forms, and results in a gradual transformation of images, finishing when the designer judges that sufficient coherence between modalities has been achieved (Goldschmidt, 1991). Therefore, we can begin see reasons why sketching may not be as or of anachronism.

Sketching is closely associated with the problem solving or ideation phase of design and can be considered as a means of externalizing ideas. Garner highlights the vital role that sketching plays

in exploring ideas and manipulating information in early concept design phase and suggests that the nature of drawing may differ widely depending on its purpose (Garner, 1990). A design process has distinct design phases each of which is characterized by the dominancy of particular types of cognitive actions. The role of sketches is not only to put ideas down on paper for later inspection, but also to induce simultaneous perception, and to facilitate a visual search, combining all available possibilities, until a plausible representation of the entity – or a meaningful aspect of it – is crystallized. Designers can perform only limited transformations in the mind when dealing with complex design situations (Goldschmidt, 1991). The limitation of storage capacity in Short Term Memory (STM) means that designers need to externalize ideas. Kolli and Hennessey observe that sketching is the most preferred in design, externalization method and in their study all of the drawings made during the conceptual stage were sketches (Kolli and Hennessey, 1993). By sketching and exploring sketches, designers find visual analogies, remember relevant examples, and discover unexpected shapes based on previously unrecognized geometric configurations in their sketches (Suwa, Gero et al., 1998). From this point of view, the sketch is not simply a representation used as a model for an artifact yet to be produced, such as a painting. Instead, it functions as an external support for images in the mind of the creator; a framework for imagination. In this sense, the sketch can only be properly comprehended by the sketcher since it is the external part of a construct that is largely in the mind of its creator.

During the conceptual developing process, creative thinking often comes from novel creative discovery, which is based on the new interpretations of figures. These interpretations, interacting with meaning association and geometric features in conceptual sketches, are not merely used for visual reference or memory assistance by designers, but utilized to produce novel visual combinations and creative transformations. The sketches, honestly recording designers' visual thinking process, are reflected a systematic dialogue between meaning association and shape attributes, and easily reach to an agreement of innovative shape and concept between different modes. In other words, the designers' interpretation are engaged in searching and discovering new meanings and shapes in sketches (Liu, 1996).

Additionally, the interpretations, interacting between meaning and shape features, might be influenced by the content of conceptual sketches, since the nature of drawing may differ widely during the different stage of design process (Garner, 1990). An idea developing process can generally be divided into an early conceptual exploring and later presenting stage. In the later conceptual stage, the design typically is focused on detail modifying, and the externalization in sketches is tidy and near real entity's appearance, which is mainly imitating the surface color, texture, and material of actual objects. However, in the early stage of conceptual developing

process, the contents of sketches are normally drawn by paper and pencil, and are scribble lines delineating object contour and configuration, or written notes to describe meanings of those figures. In this stage, design concepts are produced a great deal of quantity and visualized very quickly, and with very low degree of association among them. The majority of the conceptual sketches in the stage are presented unstructured, vague, and incomplete contour properties, which contain ambiguous and multiple meaning. The study proposed that the conceptual sketches containing vague, incomplete, and ambiguous visual properties, might be the fundamental elements for design ideas to provoke unexpected discovery and new interpretation.

This research, mainly focusing on the un-structure and ambiguous figures being produced by designers during ideation sketching, explores how the degrees of ambiguity affects designers' ideation and interpretation, and investigates the difference between experts and novices.

2. CONCEPTUAL SEKTCHING IN EARLY DESIGN DEVELOPMENT

A conceptual sketch has special cognitive meaning to its creator, because it not only can support pictorial presentation and novel conceptual expression, but also serve as a physical setting in which designers' unexpected thoughts are constructed on paper in a situated way.

The particular visual characteristics of external symbols in sketches are ones that support and facilitate the kind of visual interpretation engaged in the early stages of design, as does the actual activity of sketching(Scrivener, Clarke et al., 1992a). Sketching is closely associated with the problem solving or ideation phase of design and can be considered as a means of externalising ideas. Garner highlights the vital role that sketching plays in exploring ideas and manipulating information in early concept design phase and suggests that the development of conceptual sketches can generally be divided into two stages：exploring stage and developing stage(Garner, 1990).

In the later developing stage, the design typically is focused on details modifying, and the externalization in sketches is tidy and near real entity's appearance, which is mainly imitating the surface color, texture, and material of actual objects. However, during the exploring stage, the contents of sketches are normally drawn by paper and pencil, and are scribble lines delineating object contour and configuration, or written notes to describe meanings of those figures. In this stage, design concepts are produced a great deal of quantity and visualized very quickly, and with very low degree of association among them. Moreover, the underling meaning of concepts are indeterminacy, and the majority of the conceptual sketches in the stage are presented

unstructured, vague, and incomplete contour properties, which contain ambiguous and multiple meaning.

Exploring stage is quite similar to the Goel's early design stage(Goel, 1994) (Fig. 1). According to his study, three types of transformation can be observed in concept design stage: the first type is when designers produce new concepts without transition; the second type was that their concepts are developed extensively without obvious connection, called Lateral transformation; otherwise, the concepts are developed deeply on details, called Vertical transformation. During the early phase of design, the differences between concepts were huge; he proposed that because designers used sketches to laterally transform concepts in order to produce other different concepts. In the stage of refined and detail design, the concepts were similar and the association of concepts was higher, since designers vertically transformed their concepts on modifying the detail and partial parts. (Goel, 1994)

Design Process	Problem structure → Preliminary design → Refine design → Detail design
Creation Process	Lateral transformation → Vertical transformation

FIG.1: the process of design and creation (Goel, 1994)

In general, in the preliminary design or the early exploring stage, some typical features can be observed in the drawings, 1. The presentation of drawings is consisting of dense, unexpected, vague lines. Some were open shapes, and the perspective view of objects and geometric features were inaccurate and unstructured; 2. The conceptual development in the stage is lateral transformation, and the difference among concepts is larger. The meaning of the concept is presented abstract, vague, indeterminate and ambiguous. (Scrivener, Tseng et al., 1998; Suwa, Gero et al., 1998). Suwa, Gero, Purcell proposed that those ambiguous unstructured figures, produced unexpectedly or considerately, might facilitate designers to motivate the unexpected discovery (Suwa, Gero et al., 1998).

As the reason mention above, we can assume that the sketches, possessing the properties of ambiguous, untidy and indeterminate symbols, may keep more flexibility to facilitate designers searching the underlie features automatically, in order to provoke more novel ideas by reinterpreting the original drawings (Goel, 1994; Kavakli, Suwa et al., 1999).

3. VISUAL AMBIGUOUS PROPERTIES IN CONCEPTUAL SKETCHES

The ideation process is a series of examinations and assumptions on paper to visually present design targets or problem solutions, through interacting among perception, imagination, and recognition.

3. 1. THE CATEGORY OF VISUAL AMBIGUOUTIES

In his sketching study, Goel ((Goel, 1994)) had identified two types of visual properties, the density and ambiguity. The dense ordering of sketching, i.e., the condensing of the distance between symbols and their meanings. The ambiguity of sketches ensures that referential contents of ideas during the early phases of design are indeterminate, and that ideas are unfreeze during design development. Dense and ambiguous symbol systems play a very important role in our cognitive processes. In a study of ambiguous figure interpretations, Howard-Jones((Howard-Jones, 1998) categorized the visual properties into four different types of sketching strokes: the first category is drawn by accurate lines to form close shapes (Fig 2, a); the second category, drawn by accurate lines to form open shapes(Fig 2, b); the third category, drawn by rough lines to close shapes(Fig 2, c); the fourth category, drawn by rough lines to form open shapes(Fig 2, d).

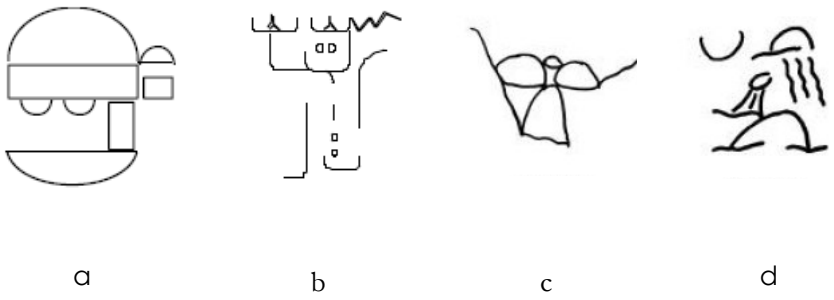


Figure 2: the four categories of visual properties of stoke lines, after Howard-Jones (Howard-Jones, 1998)

Additionally, Fish and Scrivener (Fish and Scrivener, 1990) had identified three primary attributes of the sketch. First, a sketch is composed of abbreviated two-dimensional sign systems used to represent three-dimensional visual experience. These marks operate in two ways: first they have a variety of descriptive meanings that are (partly at least) culturally acquired (e.g. a line can stand for an object boundary) and frequently such systems are supported by hand written notes; second, they are depictive in the sense that they provoke visual experience resembling that associated with the objects they represent (e.g. a line might be shaped like a facial profile). The second attribute of the sketch is that it contains selective and fragmentary information. The final attribute of the

sketch is that it contains deliberate or accidental indeterminacies. Amongst the indeterminacies commonly found in sketches are incomplete contours, wobbly lines, accidental smudges, energetic cross-hatchings, blots and scratch marks.

These different types of visual ambiguous properties, frequently observed during the conceptual developing stage, despite the fact that the line constructions build up different visual characteristics, contain vague, indeterminate meaning, and with multiple possibilities, which cause designers producing uncertain recognition, and allow multiple interpretations and thus stimulates the production of more design alternatives. Goel concluded that the sketches, possessing the properties of unambiguous, tidy and determinate symbols, severely hampered designers' creative thought processes. On the other hand, the dense and ambiguous properties of sketches are not useless or inferior, rather they play a significant part in human cognitive processes, by facilitating creative idea transformations and preventing early fixation or crystallisation during problem-solving and design development(Goel, 1994).

4. AMBIGUOUS FIGURES PRODUCED IN SKETCHING PROESS

While sketching, designers will pause of a certain length of time, usually coincided with meaningful sketch actions (Scrivener, Harris et al., 1993; Kavakli, Scrivener et al., 1998). These actions related in detail to the descriptive and depictive components of user's visual thought, and sketch production appeared to be structured such that the objects visualised were drawn part-by-part – in other words, in terms of the basic volumetric primitives comprising the object.

The segmentation and assembling sequence of object parts are influenced by structural descriptions combining with object features and geometrical relations (Marr and Nishihara, 1978; Biederman, 1987). Normally the visual system extracts lines and boundaries in terms of Gestalt-like principles to define sub-objects, which are basic shape called geons, used composed and recognised in terms of non-accidental properties, for example, intersections of located part boundaries.

Order or sequence is influenced by geometric and perceptual factors and by underlying conceptual knowledge. The object parts will be sketched one part at a time when visualised them from memory, and this reflect the geometrical construction of an

object model. The drawing behaviour represents a hierarchy of part configuration, and is affected by the decomposition of an object and that. Segmenting an object into elements and representing them in a sequence of drawings exposes the original structure underlying the sketch.

Therefore, these ambiguous unstructured figures, displayed in the idea development stage, are also visualized part by part, and the strokes are presented in a pencil based ambiguity, which is delineated along with the outline of objects in a fixed distance to make the lines thicker, such as a dense silhouette to emphasize a boundary, swaying strokes, or arbitrary scratching lines.

During sketching, vague scribble lines combined with incomplete information presented in figures will facilitate designers to elicit multiple selections. According to the structure, the ambiguous figures with the ambiguity of line display and ambiguity of category properties can be divided into three different types- close line shape, disclosed line shape and multiple line shape. These ambiguous unstructured figures can be categorized into three types, according to their visual characteristics, single occluded line shapes, single open line shapes, and multiple line shapes:

(1) Single occluded line shape : this type of figures may cause designers have a fuzzy idea of shapes, and usually can be observed during very early in idea sketching , referred to Fig 5 Step 2.

(2) Single unclosed line shapes : this type of figures may cause designers have the uncertain cognition in shape identification, and elicit more association and interpretation on geometric features and meaning through the unclosed part, and be observed during the middle of idea sketching, referred to Fig 5, step 1.

(3) Multiple line shape which includes unclosed and closed line shape : this kind of figures may cause designers have more ambiguous idea in shape and get more associations. Designers might combine and reconstruct every component while meaning and shape ambiguity will produced as well which can refer to Fig 5 in step 4 to 9.

4. METHODS

This paper, mainly focusing on the visual ambiguous properties being produced by designers during ideation sketching, explores how the degree of ambiguous figures affects designers' idea and interpretation during design development, and investigates the difference between experts and novices. The experiment included a pre-sketching session and a table design task. In the pre-sketching session, participants were asked to perform a combination drawing task in order to get ambiguous figures from their sketches.

The drawing process of the object during pre-sketching session was decomposed when participants had a long pause, at least 5 seconds, and with meaningful cognitive actions, such as thinking, looking or searching something, could be recognized and encoded from participants' protocol analysis. The degree of ambiguity was identified based on the completeness of sketched objects producing from pre-sketching session, and was classified as the highest (FIG5, Step 1), medium (FIG5, Step 4), and lowest (FIG5, Step 9) ambiguity. In the table design task, the participants, 18 experts and 18 novices, were asked to watch three different degrees of ambiguous pictures selected from the pre-sketching session. They were required to produce at least one design concept per picture presented, and were recorded for protocol analysis for analyzing and coding interpretation during conceptual developing. The definition of interpretation was referred to while participants inspected the visual stimulus and interacted with the underlie meaning to produce new interpretations, and was coded when they discovered and interpreted to a new meaning or function, or to a new form from the presented pictures.

4.1 PARTICIPANTS

A total number of 39 participants took part in the experiment. 3 of them were designated to perform the pre-sketching task, and were graduate students with one year professional design experience, in the industrial deign department at the college of design, National Yunling University of Science and Technology. The remaining 36 participants were required to performing the table design task. Half of them were undergraduate students, recruited from non-design department at the National Yunling University of Science and Technology, and had no design experience with naïve drawing skills; hence they were considered as novices. The other 18 participants were chosen from graduate and PhD students in the Industrial design department, College of Design,

National Yunling University of Science and Technology. Because of their three years professional design experience these participants were regarded as trained sketchers. All participants received a small financial reward for their participation. Participants were given a questionnaire (covering details such as, name, age, gender, course studied, years of study, design education, and design practice) prior to the experimental session.

4.2 APPARATUS AND STIMULI

The experiment was conducted in a laboratory in which the visual stimuli to be presented were placed on a table, Figure 3. Cameras were recorded participants' conceptual sketching while they were viewing the pictures.

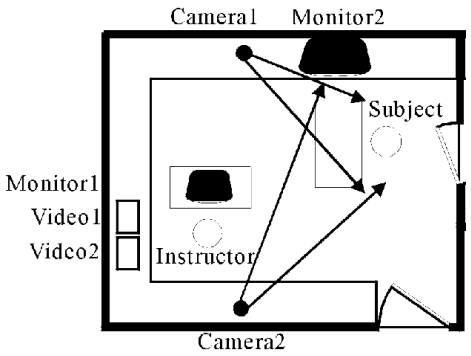


Figure 3 Experimental Layout

A workspace and drawing materials (i.e., A2 size drawing papers and black marker pens) were provided for participants to use. Camera 1 and Camera 2 were used to capture participants' free hand sketching and designing from different angles. There was also a workspace, where the two video players (Video 1 was used for recording the drawing action, and Video 2 was used for replaying sketching sessions during the interpretation session) and the three video cameras (Camera I, 2, and 3) could be controlled by the instructor. Camera 1 was focused to the right side of the sketching area, Camera 2 being placed to the left side of the designer making an angle of 30 degrees to the drawing table, and Camera 3 was used to record participants' inspecting the chairs. All cameras were all connected to a video camera controller, displayed on Monitor 1 and recorded to Video I. Monitor 2, to right of the participant's workspace, was used to replay a participant's sketching activities in the interpretation session.

4.2.1 AMBIGUOUS FIGURES

For the purpose to investigate how ambiguous or unstructured figures affects designers' interpretation during conceptual development. The ambiguous figures, used in the table design task, were created from the pre-sketching session, which instructed 3 participants to perform a design combination task. 3 paper cards, labeled a coffee cup and a hair dryer, a telephone and a hanger, and a bulb and a scissors, were presented to 3 participants. They were required to draw a least one concept (Fig 4) from the paper card presented, and were re d during their sketching process.

Fig 4, Participant 1's concepts drawn from a telephone and a hanger combination task in pre-sketching session

The sketching process of the object created during the combination task was segmented when participants had a long pause, at least 3 seconds, and with meaningful cognitive actions, such as thinking, looking or searching something, could be recognized and encoded from participants' protocol. The degree of ambiguity was identified based on the completeness of sketched objects producing from pre-sketching session, and was classified as the highest (FIG5, Step 1), moderate (FIG5, Step 4), and the lowest (FIG5, Step 9) ambiguity. These three figures were utilized as visual stimuli for participants to review in the table design task, and were named respectively "Highest Ambiguity", "Moderate Ambiguity", and "Lowest Ambiguity"(Fig 6).

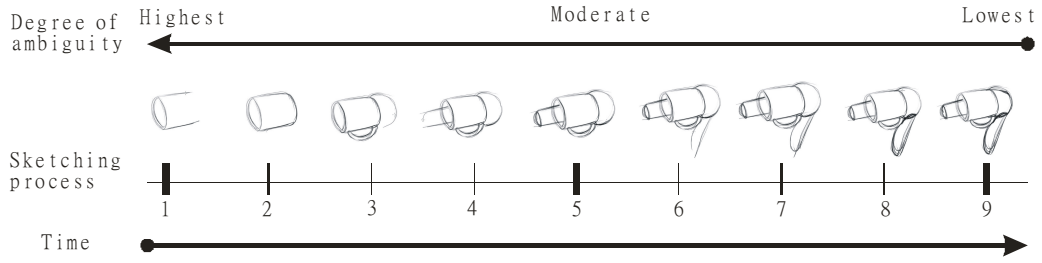


Fig 5, Participant 1's concepts drawn from a telephone and a hanger combination task in pre-sketching session

High Degree Ambiguity	Moderate Ambiguity	Low Degree Ambiguity
		

A-1	A-2	A-3
		
B-1	B-2	B-3
		
C-1	C-2	C-3

Fig 6, Three different degrees of ambiguous figures, used in the table design task

4.3 PROCEDURE

The experiment comprised two tasks: a pre-sketching task and a table design task. In the pre-sketching task, 3 participants were instructed to perform three design combination tasks, labeled a coffee cup and a hair dryer, a telephone and a hanger, and a bulb and a scissors, and required to produce a least one concept, and watched the video recordings of each sketching and described their drawing actions and sketches.

The table design was required participants to view three different degrees of ambiguous figures, based on the conceptual sketches produced in pre-sketching task. The novices were instructed not to worry about the quality of their sketches and simply do their best to represent their idea on paper. The order of presenting the ambiguous figures to all participants was A-1 B-2 C-3、A-2 B-3 C-1、A-3 B-1 C-2. Each set of figures was viewed by 3 experts and 3 novices. In the review session, participants watched the video recordings of each sketching session and described their drawing actions and sketches.

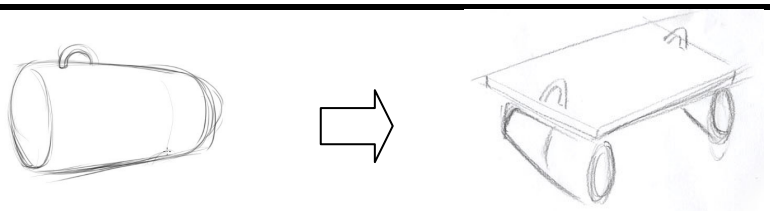
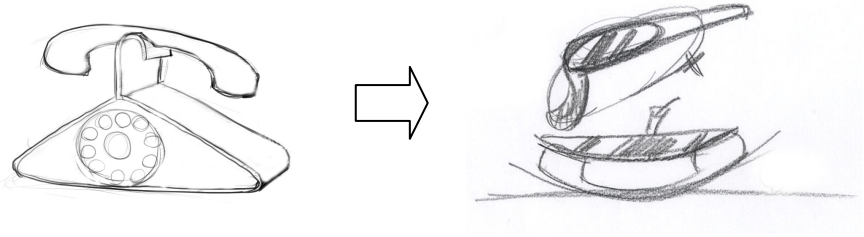
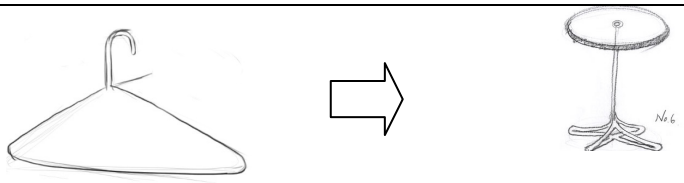
Participants were given a set of instruction, and required to fill out their name, gender, and design experience at the beginning of each task. Participants in the table design task needed to carry three design tasks, and were asked to view an ambiguous figure as a visual reference for them to design a table. Participants were required to produce at least one perspective view of the table in each design task to represent their final image. Nevertheless, they could produce as many sketches as necessary to assist them in finalising the drawing. They were instructed to desist from reproducing shadowing, patterning and using any colour effects in their sketches.

In the review session, participants were asked to review their sketching behaviour and drawings by watching the video recordings of all design tasks. While watching on video, they were requested to explain their drawing acts and sketches.

Participants were instructed that the maximum time available to them was 15 minutes for each design task, and 10 minutes for the review session. However, participants were not requested to stop and were allowed to complete drawing to their satisfaction. There was a 3 minute interval between the design tasks. The experiment lasted on average around 90 minutes, although duration varied considerable between participants.

4.3 MEASUREMENT

For the purpose of investigating the effect of ambiguous figures on designer's interpretation during conceptual sketching. Statistical comparisons were made between both groups on the production of concepts and interpretation in the table design task. Four types of interpretation had been identified, a shape associating to a new form (SS), or associating to a new function or meaning (SF), a function or meaning of form associating to a new form (FS), or associating to a new function or meaning (FF).

A shape associating to a new form (SS): Participant C was interpreted the presented cup shape figure into a shape of table legs.	
A shape associating to a new function or meaning (SF): Novice A makes use of the curve of transmitter to be the curve of the table bottom. It makes the table have the function like a tumbler.	
A function or meaning of form associating to a new form (FS): Using the idea of bending a hanger, expert D makes the form of table feet curved.	

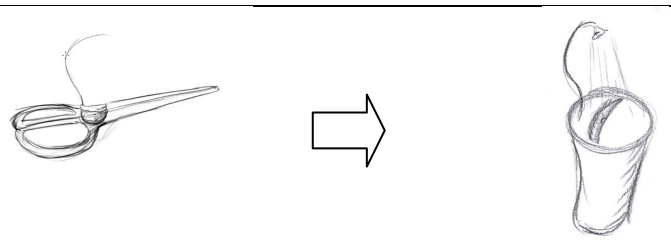
A function or meaning associating to a new function or meaning (FF): Novice B utilised the function that scissors can open and close from the handle, to make the table top can be opened and closed.	

Figure 7: 4 types of interpretation, a shape associating to a new form (SS), or associating to a new function or meaning (SF), a function or meaning of form associating to a new form (FS), or associating to a new function or meaning (FF)

5. RESULTS

The aim of the experiment was to investigate whether ambiguous figures affect designers' idea production and interpretation during design development, and whether there is any difference between experts and novices. The result section presents an analysis of production in idea and interpretation during the table design task.

5.1 IDEA PRODUCTION

The overall production of design concepts and interpretations during the table design task across both groups were 269 concepts. The experts produced more design concepts than novices' when viewing the highest ambiguous figure, but vice versa, novice's production outscored expert's during the lowest ambiguous figure viewing session. In general, the quantity of concept produced by experts was more than novices' during table design tasks.

Table 1: The idea production in both groups and in ambiguous types

	Highest ambiguity	Moderate Ambiguity	Lowest ambiguity	Total
Expert	53	46	44	143
Novice	41	38	47	126
Total	94	84	91	269

One-way ANOVA was adopted to examine whether participants' professional knowledge would influence the concept production while reviewing different degrees of ambiguous figures. Since *F* value = 3.40, is smaller than the computed critical value *F*, 22.3, we will reject the null hypotheses. This indicates that three is sufficient evidence to

indicate differences among experts' design concept production when viewing different degrees of ambiguous figures during table design tasks. However, novices' performance was not influenced by degrees of ambiguous figures in the tasks during concept development ($F = 0.27 < 7.71$).

5.2 INTEPRETATION

Participants produced totally 482 interpretations, when they interpreted a new shape from a presented shape (SS), two groups produced the highest production and percentage was 68.23%. The secondary production of interpretation was in associating to a new function from interpreting a given shape (SF), roughly about 18.92 percent. The other two interpretations, associating to a new shape from interpreting a given function (FS) and associating to a new function from interpreting a given function (FF), were produced 5.93 % and 6.9% respectively. Experts outscored novices in the production of four types of interpretation, and especially when associating to a new function or meaning from a given shape or function, their production were almost twice as much as novices', SF 79 to 17, FS 22 to 12, and FF 27 to 9. From the experiment result, the SS interpretation, associating a new shape from interpreting a given shape, was used by two groups in a large quantity during their table design development. From Table 3, the interaction between degrees of ambiguity and expert does not reach significant level, $p = 0.498 > 0.5$. However the influence of expert in producing interpretation is almost reach significant level, $P = 0.067$.

Table 2: The frequency of interpretation in expert and novices and in ambiguous types

	Highest Ambiguity				Moderate Ambiguity				Lowest Ambiguity				Total			
	SS	SF	FS	FF	SS	SF	FS	FF	SS	SF	FS	FF	SS	SF	FS	FF
Expert	52	28	8	11	54	25	5	7	64	26	9	9	170	79	22	27
Novice	45	7	4	2	48	6	5	3	53	4	3	4	146	17	12	9
Total	97	35	12	13	102	31	10	10	117	30	12	13	316	96	34	36

Table 3: Multi-variation analysis on production of interpretation in ambiguity and in two groups

Source of Variation	Value	*F* Value	*P*
Degree of Ambiguity	0.028	0.319	0.865
Expert	0.122	2.86	0.067*
Degree of Ambiguity * Expert	0.074	0.849	0.498

6. CONCLUSION AND DISCUSSION

The study was to investigate whether ambiguous figures influence designers' production of design concepts and interpretation during concept development, and there is any difference between experts and novices. The results provide compelling evidence of the effect of professional knowledge on the production of design concepts and interpretation in conceptual design development when viewing the different degrees of ambiguous figures. The experiment result is list as followings:

1. In general, experts produced more concepts than the novices', and the three degrees, highest, moderate, and lowest, of ambiguous figures had significant effect on expert's concept production, no difference was found in novices.
2. The higher the degree of ambiguous figures was, the more design concepts were produced by experts; however vice versa in novices' production.
3. In the production of interpretation, experts produced more interpretations when viewing the highest ambiguous figures than viewing the lowest ambiguous figures, but it was not reach the significant level.
4. Majority of interpretations produced by two groups during the design task were influenced by the form of presented figures, 90% interpretations associating to new forms or functions from interpreting a given shape.
5. In relating to associate new functions or meanings from a given shape or function in figures, experts significantly produce more interpretations than the novices'.

The cognitive uncertainty brought by ambiguous figures may inspire the designers to search new information in order to reduce the uncertainty. The higher the ambiguous degrees are, the more freedom and diverse types of innovations designers may have during the process of concept developments. Designers will have more horizontal transformations and interpretations in order to prevent from being stuck in the stage of problem solving and premature process of innovation.

The results could explain why these ambiguous and unstructured visual properties are habitually used by designers especially during the early phase of design development. It could imply that sketch attributes of ambiguous, accidental and indeterminate symbols

may trigger an innate recognition search mechanisms to generate a stream of imagery useful for visual interpretation. Furthermore, these special properties have the important function of assisting the mind to translate descriptive propositional information into depictions.

When viewing the highest ambiguous figures, the production of design concepts and interpretations were produced more by experts than by novices, because novices are difficult to recognize and interpreting those ambiguous figures. Novices were performed better in producing design concepts and interpretations when viewing the lowest ambiguous figures, because they simply visualize their image on paper. Experts are more persistent and increase their engagement in visual reasoning activities particularly during early phases of design. Expert designers skilful utilise visual reasoning to interpret parts or complete sketches through a series of sketches, translating them into descriptions that elicit nonexisting visual entities(Goldschmidt, 1994).

The majority of interpretations created by both groups, were elicited by associating to a new shape or new function from interpreting a given shape. The results indicate the importance of form in design development. However, compared to novices' types of interpretation, experts skillfully extract underlie function or meaning from given shapes, and interpret to a novel meaning or function, or shapes. Finally, it is concluded that early conceptual sketches that possess ambiguous, indeterminate, and unstructured figures, in fact can strengthen and facilitate expert designers' design interpretation and concept design.

Acknowledgement

The author gratefully acknowledges the support provided to this study by the National Science Council under Grant No. 95-2411-H-224-005-.

REFERENCES:

Biederman, I. (1987). "Recognition-by-components: A Theory of Human Image Understanding." Psychological Review **94**(2): 115-147.

Fish, J. and S. A. R. Scrivener (1990). "Amplifying the mind's eye: Sketching and visual cognition." Leonardo **23**(1): 117-126.

Garner, S. W. (1990). "Drawing and designing: the case for a reappraisal." Art & Design Education **9**(1): 39-55.

Goel, V. (1994). *Sketches of Thought.* Cambridge, MA, MIT Press.

Goldschmidt, G. (1991). "The Dialectics of Sketching." Creativity Research Journal **4**(2): 123-143.

Goldschmidt, G. (1994). "On visual design thinking: The vis kids of architecture." Design studies **15**(2): 158-174.

Howard-Jones, P. A. (1998). "The variation of ideational productivity over short timescales and the influence of an instructional strategy to defocus attention". Twentieth Annual Meeting of the Cognitive Science Society, Hillsdale, New Jersey, Lawrence Erlbaum Associates.

Kavakli, M., S. A. R. Scrivener, et al. (1998). "Structure in idea sketching behaviour." Design Studies(19): 485-517.

Kavakli, M., M. Suwa, et al., Eds. (1999). *Sketching interpretation in novice and expert*. Visual and Spatial Reasoning in Design. Sydney, Key Centre of Design Computing and Cognition, University of Sydney.

Kolli, R. and J. M. Hennessey (1993). "Deriving the functional requirements for a concept sketching device: A case study". Proceedings of Vienna conference on Human-Computer Interaction, Springer Verlag.

Liu, Y. (1996). "Is designing one search or two searches? A model of design thinking involving symbolism and connectionism." Design Studies **17**(4): 435-449.

Marr, D. and H. K. Nishihara (1978). "Representation and recognition of the spatial organisation of three-dimensional shapes". Proceedings of the Royal Society of London.

Scrivener, A. R., A. A. Clarke, et al. (1992a). ROCOCO: Phase 1 Report. Leics., LUTCHI Research Centre, Loughborough University, Leics.

Scrivener, S. A. R. and S. M. Clark (1993). "How interaction with sketches aids creative design". Proceedings of the International State-of-the-art Conference, Interacting with Images, National Gallery, London.

Scrivener, S. A. R., D. Harris, et al. (1993). "Designing at a distance via real-time designer-to-designer interaction." Design Studies **14**(3): 261-282.

Scrivener, S. A. R., S. W. Tseng, et al. (1998). "Uncertainty and Sketching Behaviour". Design Thinking Research Symposium, MIT, Boston, USA.

Suwa, M., J. Gero, et al. (1998). Analysis of cognitive processes of a designer as the foundation for support tools. *Artificial intelligence in design '98*. J. S. Gero and F. Sudweeks. Dordrecht, Kluwer.

Suwa, M., J. Gero, et al. (1998). "Unexpected discoveries and S-invention of design requirements: A key to creative designs". Fourth international conference on computional models of creative design, Key center of design computing and cognition, University of Sydney, Australia.

Suwa, M. and B. Tversky (1997). "How do architects interact with their design sketches in exploring design ideas?" Proceedings of 4th Australasian Cognitive Science Conference '97, Newcastle, Australia.