Role of Action Concepts in Creative Design Process

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Abstract: In this paper, the number of associative concepts is focused on, and action concept associations analyzed, in order to find out the effects of thematic relationships between concepts during the creative design process. To elucidate the mechanism of the thinking process in creative design, a series of experiments were carried out. Design tasks were selected for two different kinds of concept synthesis, with a high or a low number of associations. Protocol analysis was adopted to analyze how designers conceive other concepts during the design process. Ten design concepts by five subjects were evaluated by nine evaluators from two angles: sense and originality. Nouns, adjectives, and verbs were extracted from the protocols of each subject and divided into seven categories of associative concepts. All subjects except one subject showed higher creativity in Task B, which had a high number of associative concepts, than in Task A, with a low number of associative concepts. Given this, associating many action concepts with connect concepts in thematic relationships leads to design creativity.

Keywords: Design Creativity, Design Process, Thematic Relations, Protocol Analysis

1. BACKGROUND

Concept synthesizing is one of the key cognitive processes, especially from the viewpoint of creativity [1]. It has previously been argued that concept combining, which is a kind of concept synthesis, is effective in the generation of creative ideas [2]. It has also been reported that the distance between concepts affects creativity in the case of conceptual combining in linguistic studies [3]. As mentioned above, there have recently been studies of the relationship between creativity and concept combining, but most have been aimed at solving general problems in the field of cognitive science and linguistics. In design research, research into the creativity relevant to design is a relatively immature area that has many unsolved problems, and studies into the role of concept synthesis in design creativity are in their adolescence. So far we have focused on the following two issues when researching design creativity aimed at problems peculiar to design in the real world. First, what kind of relationship between concepts is related to higher design creativity in concept synthesis? Second, what are the characteristics of the design thinking process in concept synthesis?

The results of our studies indicate that the distance between concepts has been confirmed to relate to design creativity. This has also been identified in design experiments: the levels of abstraction in the thinking process of concept synthesis are related to levels of creativity in design [1]. We have hypothesized that when designers think at a highly abstract level their concept spaces are expanded by presenting through the design process. From this point of view, we
consider that thematic relationships between concepts have an effect upon design creativity during the expanding process by designers themselves when they are designing [4]. ‘Thematic relationships’ are the connections (a kind of similarity) between concepts made in human cognition, especially in accordance with human acts [5]. We consider that thematic relationships play important roles in the creative design process because of the relationship between concepts mediated by humans. It can be said that the design result must be meaningful to people [6]. For this reason, the designer must carefully consider not only its attributes (shape, material, and so on) but also its function and interface with the user: the human factor is very important in design creation. To recognize objects in a thematic relationship is to recognize them from the human viewpoint. Hence, it can be expected that thematic relationships between concepts during the design process are closely related to design creativity [7].

To understand the role of concept synthesis in creative design, design process should be analyzed more precisely. Therefore, in the study described here, first we focused on the number of associative concepts. An ‘associative concept’ is one that occurs when we imagine other concepts or other objects from an initial base concept or object by thinking about its properties, attributes, and values. The number of associative concepts is the number of other concepts that are imagined from, or are related to, the original (base) concept or object. The reason we pay attention to the number of associative concepts is that when people try to synthesize concepts it is probably enabling to have associative concepts in thematic relationships if the original concept is rich in associative concepts.

Second, to analyze the effects of thematic relationships between concepts in a precise way, the role of action concepts among associative concepts is identified. For that reason, we captured the process of concept synthesis as an associative process by focusing on action concepts.

**2. AIMS OF THIS RESEARCH**

To understand the mechanism of creative design thinking in terms of concept synthesis, we aimed to clarify two things: the influence of the number of associative concepts derived from two-base concepts on design creation; and the role of action concepts during the process of concept synthesis.

**3. METHODS OF THIS RESEARCH**

A set of design experiments in which the task was concept synthesis was performed. The relationships between creativity and the number of associative concepts derived from two-base concepts were investigated, to compare not only the results but also the processes of two different concept syntheses: concept synthesis with a high number of associative concepts, and concept synthesis with a low number of associative concepts.

A protocol analysis called the ‘think-aloud’ method was adopted to examine the nouns, adjectives, and verbs in the designers’ utterances [8]. We paid particular attention to the relationships between concepts, and divided the extracted words (nouns, adjectives, and verbs) into seven classes following the rules of what is regarded as the Associative Concepts Dictionary [9]. Table 1 shows an example of the classification of associative concepts of the word ‘vehicle’.
Table 1 Classification of associative concepts of ‘vehicle’

<table>
<thead>
<tr>
<th>Category of associative concept</th>
<th>‘Vehicle’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher-level Concept</td>
<td>Artificial Objects</td>
</tr>
<tr>
<td>Lower-level Concept</td>
<td>Automobile</td>
</tr>
<tr>
<td>Part/Material</td>
<td>Steering Wheel</td>
</tr>
<tr>
<td>Attribute</td>
<td>Convenience, Fast</td>
</tr>
<tr>
<td>Synonym</td>
<td>Thing to Ride</td>
</tr>
<tr>
<td>Action</td>
<td>To Run, To Fly</td>
</tr>
<tr>
<td>Situation</td>
<td>Road, Railroad</td>
</tr>
</tbody>
</table>

4. DESIGN EXPERIMENTS

4.1 Design Tasks

First, 20 types of words to set base concepts were selected in each group—artificial objects and natural objects—to decide on the design tasks. The 20 selected words were “mirror”, “glasses”, “bag”, “letter”, “chair”, “scissors”, “pool”, “guitar”, “blanket”, “thermometer”, “flower”, “dog”, “fish”, “bird”, “milk”, “water”, “oil”, “egg”, “star”, and “ice”.

Next, the number of associations from each word was calculated by using the Associative Concepts Dictionary. The Associative Concepts Dictionary is an electronic dictionary that was formed from lists of large numbers of words evoked from the mention of selected basic words from a fundamental vocabulary, in order to extract information on the human language. It was established from the result of a large-scale experiment on associative concepts. Table 2 shows the number of associations of the 20 selected concepts.

Using the Associative Concepts Dictionary, we counted all associative concepts from one stimulus word to calculate the number of associations. In addition, we also measured the distances between selected concepts in accordance with the EDR Concept Dictionary in order to choose pairs of words with equal distances between concepts for the design tasks [10]. These pairs were called ‘two-base concepts’. It has been reported that, in concept combination, the distance between concepts affects design creativity [1]. Therefore, to compare the levels of creativity related to different numbers of associations, we needed to regulate the distance between concepts in our experiment to exclude their effects on creativity. To determine the distances between concepts, we defined the ‘distance’ as the number of steps between two concepts in the hierarchy of concepts defined in EDR.

In the Concept Dictionary, more than 150 000 kinds of words are structured as a hierarchy of concepts. For instance, the distance between ‘vehicle’ and ‘blanket’ is counted within this structure as seven steps (four steps from vehicle to inanimate object and then down three steps to blanket; Figure 1). We measured the distances between any pairs of the 20 selected concepts in this way.

Pairs of words with equal distance conditions between concepts were selected as keywords for the design tasks. From our measurement of the distances between concepts, two kinds of pairs of natural and artificial objects were selected for the design tasks in concept synthesis. For Task A, ‘egg’ and ‘blanket’, which had a low number of associations, were selected. For Task B, ‘flower’ and ‘mirror’ which have a high number of associations, were selected. Table 3 shows the number of associations of the words ‘egg’ and ‘blanket’ and ‘flower’ and ‘mirror’. ‘Vehicle’ was selected as the design goal, because it was equidistant from ‘egg’ and ‘blanket’ and ‘flower’ and ‘mirror’ (Figure 1).
The design tasks given to the subjects in this experiment were as follows:

- Task A: Design a new vehicle from the words ‘egg’ and ‘blanket’ (low number of associations)
- Task B: Design a new vehicle from the words ‘flower’ and ‘mirror’ (high number of associations)

Table 3 shows the difference of the number of associations of each concept for the two kinds of design tasks.

<table>
<thead>
<tr>
<th>Artificial Objects</th>
<th>Number of Associations</th>
<th>Natural Objects</th>
<th>Number of Associations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mirror</td>
<td>114</td>
<td>Flower</td>
<td>151</td>
</tr>
<tr>
<td>Glasses</td>
<td>110</td>
<td>Dog</td>
<td>127</td>
</tr>
<tr>
<td>Bag</td>
<td>97</td>
<td>Fish</td>
<td>115</td>
</tr>
<tr>
<td>Letter</td>
<td>93</td>
<td>Bird</td>
<td>112</td>
</tr>
<tr>
<td>Chair</td>
<td>91</td>
<td>Milk</td>
<td>91</td>
</tr>
<tr>
<td>Scissors</td>
<td>81</td>
<td>Water</td>
<td>85</td>
</tr>
<tr>
<td>Pool</td>
<td>75</td>
<td>Oil</td>
<td>78</td>
</tr>
<tr>
<td>Guitar</td>
<td>74</td>
<td>Egg</td>
<td>71</td>
</tr>
<tr>
<td>Blanket</td>
<td>69</td>
<td>Star</td>
<td>64</td>
</tr>
<tr>
<td>Thermometer</td>
<td>68</td>
<td>Ice</td>
<td>52</td>
</tr>
</tbody>
</table>

Figure 1 Method of measurement of distance between concepts
Table 3 Number of association of each concept

<table>
<thead>
<tr>
<th>Task</th>
<th>Natural objects</th>
<th>Artificial objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Egg (71)</td>
<td>Blanket (69)</td>
</tr>
<tr>
<td>B</td>
<td>Flower (151)</td>
<td>Mirror (114)</td>
</tr>
</tbody>
</table>

4.2 Subjects of the experiments

Five subjects participated in the experiments. They were two non-design students, two design students (of an Art University), and a professional designer.

4.3 Structure of the design experiments

The structure of the design experiment for each task was as follows:

- Before the design sessions

Before the experiments, concept synthesis was explained to the subjects by using design examples. To guide them on how to synthesize the concepts successfully, the subjects were told that they could abstract the two concepts as long as the final result inherited a certain feature from each. After the explanation, a preliminary experiment (5 min) was carried out. The task involved designing a new entity by synthesizing two different entities (namely, a ‘glass’ and a ‘bird’). These two concepts were selected from a previous study of concept synthesis to lead to high levels of creativity in design [1].

- Design sessions (10 min. x 2 times)

Five subjects were asked to work on design Task A and B in concept synthesis at random (to eliminate the influence of task order, subjects 1, 3, and 5 started with task A and subjects 2 and 4 started with task B).

The subjects generated new design ideas with sketches and proposed one final design idea for each task. During these design sessions, the subjects were required to verbalize their thoughts. Examiners recorded the subjects’ utterances, behaviour, and sketching processes during the tasks. As the final design, each subject selected his or her best concept design from at least two of the ideas they had drawn. Two cameras from two different angles recorded the drawing process and the subject’s behaviour during the design session.

- Interview session (30min. x 2)

Each subject was asked to answer questions about his or her design process in a semi-structured interview that was recorded on video. Subjects were asked to explain the reasons for their ideas to an examiner. For example, “Why did you draw a heart of this shape?” “Why did you say an apple?” The reason for these questions was to examine the kinds of concepts that they associated with other concepts, in order to divide the ideas into seven categories of
associative concepts.

To determine the source of the concept associations in this experiment, the interviews consisted of two stages of arranged questions based on previous research by Taura et al. [11]; the original questions had been formulated to determine the reasons behind the design.

The questions in the first stage were used to search for the design reason associated with the concepts. The questions in the second stage were about the substance of the design reason.

The conditions for stopping each question were as follows.

1) When the subject could not answer the question any further. However, if it was a first stage question the interviewer would ask the same question again in the second stage.

2) When the answers were the same as the subject had given before.

3) When more than four other subjects had given the same answer to the same question.

4.4 Evaluation of concept of design results

The outcomes of the design sessions were evaluated by the method of Finke et al. [2]. Items were evaluated from two perspectives—sense and originality—on a four-point scale by an evaluator for each perspective. Design outcomes evaluated as less than 2.0 points for sense were omitted.

5. ANALYSIS

To avoid the influence of differences in sketching skill, the design results were described by the examiner as summaries of the design concept. Each summary expressed the design concept with regard to the subject’s sketches, utterances, and answers to the semi-structured interviews.

5.1 Results of evaluation

Nine evaluators (two professional designers and seven design professors) evaluated 10 kinds of design concept as outcomes of the design session. Table 4 shows the results of the evaluation.

In this research, we paid attention to differences in the results between task A and task B for each subject to investigate the influence of the number of associations on creativity. Following rules of creativity evaluation, we compared the subjects’ scores on task A and task B for originality. The result was that only Subject 1 had the same score in both task A and task B. The score for originality for Subject 2, 3, and 4 were higher for Task B than for Task A. The two-sided t-test showed that there was a significant difference between Task A and B in terms of the originality result. However, there was there was no significant difference between Task A and Task B for the sense result.

Subjects 1 and 2 were the design-inexperienced people, and Subjects 3 and 4 were design students of an art university. Subject 5 was a professional designer. Subjects made one to three sketches during each design session while thinking of new design concepts. However, in this experiment, the evaluators judged only the described concept, without the sketches.
Table 4 Results of Evaluation

<table>
<thead>
<tr>
<th></th>
<th>Significance n.s</th>
<th>Originality *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Task A</td>
<td>Task B</td>
</tr>
<tr>
<td>Subject 1</td>
<td>2.4</td>
<td>2.3</td>
</tr>
<tr>
<td>Subject 2</td>
<td>1.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Subject 3</td>
<td>2.1</td>
<td>2.3</td>
</tr>
<tr>
<td>Subject 4</td>
<td>2.4</td>
<td>2.3</td>
</tr>
<tr>
<td>Subject 5</td>
<td>2.1</td>
<td>2.4</td>
</tr>
<tr>
<td>Average (SD)</td>
<td>2.08(0.41)</td>
<td>2.34(0.05)</td>
</tr>
</tbody>
</table>

Two-sided t-test (n.s.: \( p > .10 \), *: \( p < .10 \))

Design concepts for Task A and Task B for each subject were as follows:

- **Subject 1**
  - **Task A**: Attraction that resembles a capsule toy (‘Gashapon’)[12]
    This is a playground attraction that looks like a capsule toy. There are four rails to hold and riders can slide safely on the rails. The inside of the capsule is covered with cushions.
  - **Task B**: Stealth car that uses biomass energy
    High technology is employed to protect the object from detection or from being seen. This car runs on biomass energy.

- **Subject 2**
  - **Task A**: A bicycle with a blanket cover
    A blanket is spread on the tatami (a Japanese mat) and people can ride a blanket-covered tricycle. There are three wheels under the tatami and the bicycle is powered by an electric motor. Handling is easy and riders can lie down on the bike comfortably.
  - **Task B**: A car that shrivels up if driven roughly
    Good drivers can nurture this car to make it more beautiful. ‘Good driving’ refers not to the driving technique but to the warm heart that cares for others. However, if driven roughly, the car will shrivel.

- **Subject 3**
  - **Task A**: A car that looks like an egg
    The front covering of the car body is transparent, and it can be opened like an egg. A driver can get into the car through this open part. The interior of the car is covered with fur. It is pure white and can carry a maximum of two people.
  - **Task B**: A tanker (a kind of ship) where flowers are cultivated in a huge planter
This tanker has a huge planter on top. There is a mirror above the planter so that sunlight always reflects onto the planter.

Subject 4

Task A: Egg slider attraction

Riders can go inside the egg and slide down a half-pipe shaped like half an egg. The inside of the egg is covered in soft material so that the rider can lie down. The egg has a double-layered structure that works like a gyroscope to enable people to lie down comfortably while sliding.

Task B: Kaleidoscopic train/bus that uses scenery reflected through a window

There is a pair of sofas in the coach of a train/bus. They face each other with mirrors behind them. These mirrors also face each other. There are windows next to them, and when the train or bus passes through a field of flowers, it creates a kaleidoscopic view that changes with the reflection.

Subject 5

Task A: Flying ‘Love Board’

This is a disk-shaped board about 10 cm in diameter than can fly. The centre part of the disk glitters and presents words or photographs. Young lovers enjoy riding on the disk and recording their conversation. They can play back their conversation when they push the glittering part of the disk.

Task B: Cylindrical relaxation elevator

This elevator doesn’t work to transfer from one floor to another, but instead for seeing oneself as a user in a slowly moving space. Water falls on the surface of the cylinder every 3-4 minutes. People are healed within this elevator. A personal gondola goes up and down slowly in the cylinder and the user can sleep, think, meditate, or look outside. (about 100 m height and 1.5 m diameter)

5.2 Procedure of protocol analysis

The procedure used for protocol analysis was as follows:

1) The subject’s utterances during the design session were written down as text
2) All text was analyzed by ‘ChaSen’, which is the prime for the text mining of Japanese language [13], and was divided into nouns, adjectives, and verbs. Exclamations were omitted.
3) All words (nouns, adjectives, and verbs) were classified into seven categories of associative concept (higher-level concept, lower-level concept, part/material, attribute, synonym, action, situation), using Associative Concept Dictionary [9].
4) The proportion of words in each category was calculated.

5.3 Results of protocol analysis

Nouns, adjectives, and verbs were extracted from the protocols of each subject and divided into seven categories of associative concepts. For example, extracted protocol (words) are car, flower, bicycle, polish, clean, beautiful, from utterances of a subject; “um” “a car and flower”, “let me see”, “I can not have any imagination”, ~ “oh, the time past
so quickly, but I can’t see”, “yes, a bicycle” “then”, “If I polish a bicycle, it will be clean” “clean and beautiful”.

Table 5 shows a part of associative concept dictionary. It shows associative words from the stimulus word ‘vehicle’. For example, “bicycle” is categorized as one of lower-level concepts of vehicle (procedure 3). Then, “bicycle” is chosen as an associative concept of “vehicle” and classified into the category of lower-level concepts.

Table 6 shows an example of the results of a classification of protocols into associative concepts.

Table 5 A part of Associative Concept Dictionary

<table>
<thead>
<tr>
<th>Stimulus Word</th>
<th>Categories</th>
<th>Associative Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle</td>
<td>Lower-level Concept</td>
<td>Motorcycle</td>
</tr>
<tr>
<td>Vehicle</td>
<td>Lower-level Concept</td>
<td>Ferris Wheel</td>
</tr>
<tr>
<td>Vehicle</td>
<td>Lower-level Concept</td>
<td>Bicycle</td>
</tr>
<tr>
<td>Vehicle</td>
<td>Lower-level Concept</td>
<td>Horse</td>
</tr>
<tr>
<td>Vehicle</td>
<td>Lower-level Concept</td>
<td>Tricycle</td>
</tr>
</tbody>
</table>

Table 6 Classification of protocols into associative concepts

<table>
<thead>
<tr>
<th>protocol</th>
<th>Part of speech</th>
<th>Categories of associative concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>car</td>
<td>noun</td>
<td>lower concept of a vehicle</td>
</tr>
<tr>
<td>flower</td>
<td>noun</td>
<td>&lt;basic concept&gt;</td>
</tr>
<tr>
<td>bicycle</td>
<td>noun</td>
<td>lower concept of a vehicle</td>
</tr>
<tr>
<td>to polish</td>
<td>verb</td>
<td>Action concept of a mirror</td>
</tr>
<tr>
<td>beautiful</td>
<td>adjective</td>
<td>attribute concept of mirror and flower</td>
</tr>
</tbody>
</table>

We examined the rates of each associative concept in the complete protocol of each subject. Attention was paid to the difference between task performances for each subject, especially in terms of the rates of action concepts for each task, because this was expected to play a role in making connections between the concepts in thematic relationships. In the case of Subject 1, the rate of action concepts in Task A was higher than in Task B. For Subject 2, the rate of action concepts in Task B was higher than in Task A, according to the relationship with the creativity score; the score in Task B was higher than that in Task A. The results for Subjects 3, 4, and 5 were the same as for Subject 2; the rate of action concepts in Task B was greater than that in Task A, according to the relationship with the creativity score and, the score in Task B was higher than in Task A.

Figure 2 shows the average for each category of associative concepts among protocols. More action concepts were
expressed out loud in the case of Task B, which also showed a higher creativity score. However, there was no significant difference between the tasks.

Except in the case of Subject 1, all subjects imaged and uttered of action concepts for Task B, that had higher creativity scores than for Task A (Figure 3).

![Figure2. Average of each category of associative concept](image_url)

### 6. RESULTS OF THE EXPERIMENTS
When compared the results of tasks A and B for each subject, all subjects except subject 1 showed greater creativity in task B than in task A. This suggests that synthesis between two concepts that have a high number of associations leads to higher creativity in design outcomes.

The results of the sense scoring for all subjects showed that the sense score was not affected by the number of associations with the base concepts. The results of the originality score showed that all subjects except subject 1 achieved a higher creativity score in task B than in task A. This means that the number of associative concepts affected not the sense dimension but the originality dimension, and it indicates that a high number of associative concepts lead to higher design creativity in concept synthesis.

On the other hand, when we focus on differences in the rate of protocols during the processing for task A and for task B, it can be understood that all subjects apart from subject 1 showed a higher rate of action concepts for task B than for task A. From this, it is inferred that synthesis between concepts with a high number of associations stimulated action concepts as associative concepts during the process of design by the subjects. Therefore, it could be said that action concepts are related to creativity in concept synthesis.
7. CONCLUSION
This research first discussed the influence of the number of associations on design creativity in concept synthesis. The results of our experiments showed that the synthesis of concepts in relationships between two base concepts that have a high number of associative concepts leads to greater creativity. Second, the association of many action concepts that act to connect the concepts in thematic relationships leads to design creativity. To enhance higher creativity in design, practices in educational program of concept synthesis can be effective in such conditions of base concepts, Relationships of base concepts for design practice in concept synthesis is rich of associative concepts; action concept and situation concepts.

We investigated a role of action concept which was one of associative concepts, to connect knowledge on objects to knowledge on human within thematic relations. As the result, we conclude that to merge thematic relations among concepts, associative concepts in scenarios are effective for designers to let them think of functions of products and meanings for the users. When scenario creations are successfully worked, designers thought up novel concepts of products.

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