Concept Blending and Dissimilarity: Factors for Creative Design Process: A Comparison between the Linguistic Interpretation Process and Design Process

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Concept Blending and Dissimilarity

Factors for Creative Design Process
A Comparison between the Linguistic Interpretation Process and Design Process

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Abstract

This study investigated the design process in order to clarify the characteristics of the essence of the creative design process vis-à-vis the interpretation process, by carrying out design experiments. The authors analyzed the characteristics of the creative design process by comparing it with the linguistic interpretation process, from the viewpoints of thought types (analogy, blending, and thematic relation) and recognition types (commonalities and alignable and nonalignable differences). A new concept can be created by using the noun-noun phrase as the process of synthesizing two concepts—the simplest and most essential process in formulating a new concept from existing ones. Furthermore, the noun-noun phrase can be interpreted in a natural way. In our experiment, the subjects were required to interpret a novel noun-noun phrase, create a design concept from the same noun-noun phrase, and list the similarities and dissimilarities between the two nouns. The authors compare the results of the thought types and recognition types, focusing on the perspective of the manner in which things were viewed, i.e., in terms of similarities and dissimilarities. A comparison of the results reveals that blending and nonalignable differences characterize the creative design process. The findings of this research will contribute a framework of design practice, to enhance both students' and designers' creativity for concept formation in design, which relates to the development of innovative design.

Keywords

Noun-Noun phrase; Design; Creativity; Blending; Nonalignable difference

At present, a large number of noteworthy studies have been conducted to elucidate the characteristics of the thinking process in design (Cross, 2001; Lawson, 1993; Schon, 1988; Stauffer and Ullman, 1988) in order to understand the nature of design creativity. Based on the studies conducted on designers' thinking processes, various arguments regarding the cognitive process underlying design creativity have been empirically investigated (Bonnardel and Marmeche, 2004; Casakin and Goldschmidt, 1999; Dorst and Cross, 2001; Visser, 1992), and the meta-cognitive level of design knowledge among people or in the context of the designers' behaviour (Bilda, Candy and

Edmonds, 2007; Dong, 2006; Suwa and Tversky, 1997) have been presented. To understand design knowledge, a theoretical approach towards the features of design strategy has been adopted on the basis of the relationships between the concept and knowledge (Taura and Yoshikawa, 1992; Hatchuel, Masson and Weil, 2004); this approach has established a framework for the concept-forming process of design from the viewpoint of creativity. Moreover, several notable investigations on design cognition, which employ analytical approaches targeting important factors or conditions for the designers' high creativity, have been reported (Jin and Chusilp, 2006; Liu, Bligh and Chakrabarti, 2003); moreover, the importance of implicit or embodied knowledge in design has been addressed with respect to real-world design (Rust, 2004). The knowledge in creative design is cultivated not only to generate innovative ideas but also to manage the endeavours of design at the social level (Friedman, 2003).

As mentioned above, many studies have been conducted to analyze the characteristics of the thinking process in design from the viewpoint of creativity (hereafter called creative design process). However, thus far, the nature of creative design process has not been thoroughly clarified.

In this paper, as an extension of our previous study(Taura, Nagai, Morita, and Takeuchi, 2007) , we attempt to capture the essence of creative design process another approach by (1) comparing the creative design process with a non-design creative process and (2) analyzing the essence of creativity from the viewpoint of the manner in which things are viewed.

With respect to (1), the design process is compared with the linguistic interpretation process, and with respect to (2), we focus on the dissimilarities between the two processes.

In this study, as an exemplar of the design process, the process of synthesizing two concepts (hereafter called base concepts) is addressed; this is because it is the simplest and the most essential process in formulating a new concept from the existing ones (Rothenberg, 1979; Lubert, 1994). Furthermore, this process is suitable for this study due to the following reasons. In this study, the term `concept' is used to represent not only the image but also the object (natural and artifactual) that is kept in mind.

First, this process is found in an actual field. Empirically, the invention of the art knife—the first snap-off blade cutter—is an appropriate example (Figure 1). The inspiration for this incredible idea stemmed from the synthesis of two concepts—chocolate segments that can be broken off and the sharp edges of broken glass (Taura, Nagai and Tanaka, 2005).

Innovation of the art knife (the first snap-off blade

Fig 1. Design idea for an art knife by combining two concepts—broken glass and chocolate segments

Second, this process involves typical important design processes: analogical reasoning, concept blending, and concept integrating.

Analogical reasoning is known to play a crucial role in creative design process (Gero and Kazakov, 1998; Gero and Maher, 1993; Cross 2006). It is also considered to be a concept creation method involving the transfer of some features from an existing concept to another concept. Nagai and Taura (2006) identified the process of analogy in design as type of concept synthesizing process and found other types. They classified concept synthesizing processes into three types (analogical reasoning, concept blending, and concept integrating) as above. However the factors in differences among the three types and details of cognitive processes among them have not been clarified. In practice, it is frequently used in the design process and is regarded as the most effective design process with respect to the synthesis of two concepts. For example, the concept of a 'white tomato' can be formed from two individual concepts, namely, 'tomato' and 'snow' (Figure 2).

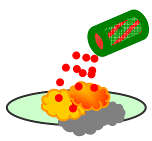
Design processes	Analogical reasoning	Concept blending	Concept integrating in a thematic relation
	e.g. 'white tomato' for *snow-tomato* 	e.g. 'powdered ketchup' for *snow-Tomato* 	e.g. 'humidifying refrigator' for a *snow-tomato* 

Fig 2. Three types of concept-synthesizing processes (snow-tomato)

On the other hand, in studies on cognitive linguistics, Fauconnier (1994) analyzed how conceptual integration develops mental products, and the manner in which one can position the systems of mapping and blending between mental spaces. He demonstrated that conceptual integration operates on two input mental spaces to yield a third space, which is termed 'the blend'. This blended space inherits partial structural features from the input spaces and has emergent structural features of its own (Fauconnier and Turner, 2002). This concept blending is also a type of concept-synthesizing process. For example, from 'tomato' and 'snow', the concept of 'powdered ketchup', which is used like powdered cheese on a dining table, can be designed.

Further, in research on recognizing the relation between two concepts, it has been revealed that there are two types of relations—taxonomical and thematic—between two concepts (Shoben and Gagne, 1997). The former is a relation that represents the physical resemblance between two objects, and the latter represents the relation between two concepts through a thematic scene. In design, the result (hereafter called design product) must be meaningful to people. Therefore, the designer must carefully consider not only the design product's attributes (shape, material, etc.) but also its function and interface; in other words, consideration of the human element is important. Consequently, concept integration—in which the concepts are synthesized by using the thematic relation—is found to play a very important role in the creative design process. With respect to the example of 'tomato' and 'snow', the concept of a 'refrigerator that can humidify the food in it' is designed from the scene of the situation: a tomato stored in snow.

As mentioned above, it is found that all three essential design processes—analogical reasoning, concept blending, and concept integrating—can be discussed on the basis of the concept-synthesizing process.

Third, by considering the two base concepts as a compound phrase composed of two nouns (hereafter called noun-noun phrase), one can compare the design process with the linguistic interpretation process. In the field of linguistic studies, many results have been regarding the study of noun-noun phrases ,(Costello and Keane, 2000 ; Hampton, 1997 ; Wisniewski, 1996). In particular, the interpretation process of noun-noun phrases has been intensively investigated (Wisniewski, 1996). Therefore, noun-noun phrases can be used as the base concepts from which a new concept is designed and the phrases can be interpreted.

In the field of linguistic studies, it is revealed that a novel noun-noun phrase is interpreted through three processes: property mapping, hybrid linking, and relation linking (Wisniewski, 1996). For example, a knife-fork can be interpreted as follows: a knife-shaped fork, through the property mapping process; one-half as a knife and the other half as a fork, through the hybrid linking process; and a knife and fork set used together while eating, through the relation linking process (Figure 3).

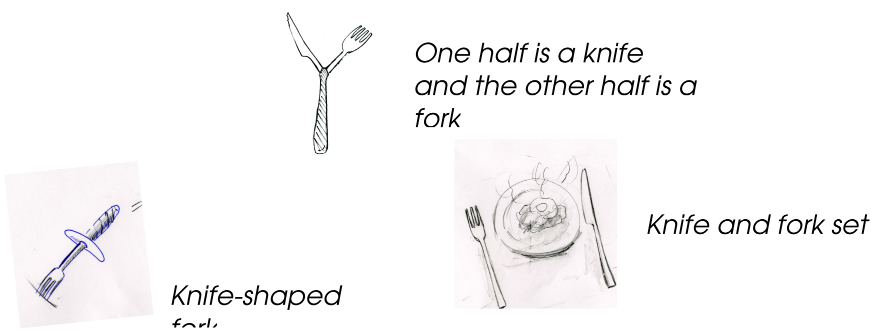


Fig 3. Three types of interpretation processes for the noun-noun phrase (Knife-fork)

We were able to clarify the three types of linguistic interpretation processes corresponding to the concept-synthesizing process in the above design and categorize them, as presented in Table 1 (Nagai and Taura, 2006). By using this correspondence, the design process can be compared with the linguistic interpretation process. Hereafter, the term 'analogy' is used to represent the thought type that involves property mapping in the linguistic interpretation process and analogical reasoning in the design process. In the same manner, the term 'blending' is used for hybrid linking and concept blending, and 'thematic relation' is used for relation linking and concept integration.

Table 1: Classification of the process types for both the linguistic interpretation and design processes

	Analogy	Blending	Thematic relation
Linguistic Interpretation process	Property mapping (e.g. 'a knife-shaped fork' for *knife-fork*)	Hybrid linking (e.g. 'one-half is a knife and the other half is a fork' for *knife-fork*)	Relation linking (e.g. 'a knife and fork set' for *knife-fork*)
Design process	Analogical reasoning (e.g. 'white tomato' for *snow-tomato*)	Concept blending (e.g. 'powdered ketchup' for *snow-tomato*)	Concept integration in thematic relation (e.g. 'humidifying refrigerator' for *snow-tomato*)

In our previous experiment, it was revealed that the proportion of analogy was lower in the design tasks than in the interpretation tasks. In contrast, the proportion of blending was higher in the design tasks than in the interpretation tasks (Taura, Nagai, Morita, and Takeuchi, 2007). This result indicates that the nature of the design process is based on blending. The reason for this is assumed to be as follows: Design products developed by analogical reasoning are limited in terms of originality, since analogical reasoning cannot extend beyond the domain of the given concept. In contrast, concept blending can develop a truly new concept, because the concept developed by this process does not belong to either domain of the base concepts. Therefore, concept blending is assumed to characterize the design process, which pursues the high originality. On the other hand, in the interpretation process, the given phrases are interpreted naturally. Therefore, it is assumed that concept blending is used more in the design process than in the interpretation process. However, with respect to this assumption, we conducted the experiment only once. Therefore, this assumption needs to be confirmed by conducting a second and plenary experiment. Further, the mechanism of the blending operation in the design process needs to be investigated in order to verify this assumption.

In this study, we focus on recognition types (commonalities and alignable and nonalignable differences). Markman and Wisnieski (1997) explained the concepts of alignable and nonalignable differences as follows: 'Alignable differences are coded for both references to values along a single dimension, such as a sled carries more than one person and a ski carries only one person, as well as for implicit references, such as sleds and skis carry different number of people. Nonalignable differences are coded for all other differences that were listed. These differences simply focused on a disparity between the two items without highlighting a common dimension. An example of a nonalignable difference would be that an airplane is solid but a puddle is not'. Further, it was reported that more commonalities and alignable differences were listed for similar pairs than for dissimilar pairs, while more nonalignable differences were listed for dissimilar pairs than for similar pairs (Markman and Wisnieski, 1997; Wilkenfeld and Ward, 2001).

Now, let us focus on the recognition types in the concept-synthesizing process.

First, let us consider analogical reasoning. Analogical reasoning is considered to involve the transfer of some features from an existing concept to another concept. Therefore, the feature recognized in analogical reasoning is assumed to be an alignable difference, since in analogical reasoning, the feature recognized in the existing concept displaces the corresponding feature in another concept, and this displacement implies that both these features involve different values along a single dimension. For example, 'white tomato' in Figure 2 is obtained by transferring the feature of 'white' to 'tomato'. Here, the recognized feature 'white' is classified as an alignable difference, since 'white' is the value of colour and tomato has another value of colour, i.e. 'red'. On the other hand, in concept blending, the features recognized in the two synthesized concepts need not be alignable, since these two features are blended to yield a new concept. For example, in 'powdered ketchup' in Figure 2, the recognized feature 'powder' is classified as a nonalignable difference, since the corresponding feature of 'powder' is thought to be non-recognizable in 'tomato'. Therefore, the nonalignable difference is assumed to be related to concept blending in the design process.

Further, in our previous study, it was found that if the base concepts are very dissimilar, a highly creative design product may be obtained (Taura, Nagai, and Tanaka, 2005). By reconsidering this finding from the viewpoint of recognition types, we can assume that the creativity in concept blending is related with recognition of the base concepts as those with nonalignable differences.

Based on the above consideration, we constructed the following hypotheses:

1. The concept blending process characterizes the design process.
2. Nonalignable differences are related to concept blending and creativity in the design process.

Although we clarified the two hypotheses as given above, the following questions remain unanswered.

First, is the recognition process of the nonalignable differences manifested during the design process, or it is an inherent trait? This is a very interesting question from the viewpoint of learning or teaching the design process.

Second, what is the causal relation between the nonalignable differences and blending? Which one is the cause of the other?

The first question is investigated in the experiment, and the second one is discussed at the end of this paper.

Outline of the Experiment

In the experiment, the subjects were required to perform three tasks: interpret a novel noun-noun phrase (interpretation task), create a new concept from the same noun-noun phrase (design task), and finally, list the similarities and dissimilarities between the two nouns (similarity and dissimilarity listing task). Prior to the experiment, we conducted a preliminary experiment in order to select the noun-noun phrases to be used in the main experiment. The first and second tasks in the main experiment were conducted in order to verify hypotheses (1) and (2). The third task was conducted in order to answer the first question.

The responses obtained were analyzed from the viewpoints of thought types (analogy, blending, and thematic relation) and recognition types (commonalities, and alignable and nonalignable differences). Further, the creativity in the design products was analyzed as follows: First, the design products were evaluated from the viewpoint of originality and practicality. Second, the features enumerated by explaining the design products and the responses to the interpretation task were judged, also whether or not they were emergent features.

Interpretation task

The interpretation task consisted of two sub-tasks. First, the subjects were asked to naturally interpret the noun-noun phrases (termed the 'Interpretation Task'). Second, they were required to some words (termed 'interpretation feature') to explain each interpretation (termed as the 'Interpretation Feature Enumerating Task'). The responses to the Interpretation Task were analyzed from the viewpoint of thought types. The responses to the Interpretation Feature Enumerating Task were analyzed from the viewpoint of recognition types and the emergence of features.

Design task

The design task also consisted of two sub-tasks. First, the subjects were required to design a new concept from the noun-noun phrases (termed the 'Design Task'). They were required to not only draw a sketch of the concept, but also to explain the concept by using the terms in a sentence. Second, they were required to enumerate some words (termed as 'design feature') to explain the features of each concept (termed the 'Design Feature Enumerating Task'). The design products (hereafter, the term 'design product' is used to imply something that involves not only a sketch, but also the sentence which describes it) are analyzed from the viewpoint of thought types and creativity (originality and practicality). The responses to the Design Feature Enumerating Task are analyzed from the viewpoint of the recognition types and the emergence of features.

Similarity and dissimilarity listing task

In this task, the subjects were required to compare the two nouns of the noun-noun phrase used in the Interpretation Task (as well as the Design Task) and to list the common (similarities) and different features (dissimilarities) (termed the 'Similarity and Dissimilarity Listing Task'). The responses to the Similarity and Dissimilarity Listing Task were analyzed from the viewpoint of the recognition types.

Experimental Method

Selecting the noun-noun phrases used in the preliminary experiment

The noun-noun phrases to be used in the preliminary experiment were selected according to the following procedures.

First, for the 1055 words listed in the associative concept dictionary (Ishizaki, 2007), the number of associations of each word was investigated, and the words whose associations were between 168 and 299 (±δ) were selected in order to control the associative effectiveness (Wilkenfeld and Ward, 2001) in design; as a result, 698 words were selected. Next, these selected words were classified into eight categories (furniture, musical instrument, container, natural item, artificial item, tool, wheeled vehicle, and non-wheeled vehicle) and exceptions by referring to the method mentioned in Wilkenfeld and Ward (2001). Finally, 20 noun-noun combination phrases were selected at random such that the two nouns of each phrase did not belong to the same category. These 20 noun-noun combination phrases were selected to be used in the preliminary experiment.

Preliminary experiment for selecting noun-noun phrases used in the main experiment

In the preliminary experiment, 18 subjects were asked to compare two words and list the common (similarities) and different features (dissimilarities) between the two. We planned to select the noun-noun phrases such that the number of listed common and different features was approximately the same and the variance was large; this was done according to the following guidelines:

- The difference between the mean of the number of common features and that of different features is lower than the average (0.6).
- The standard deviation of the number of common features is higher than the overall average (1.0).
- The standard deviation of the number of different features is higher than the overall average (1.1).

As a result, the following six noun-noun phrases were chosen: **ship-box**, **piano-guitar**, **desk-elevator**, **drawer-plate**, **ship-guitar**, and **book-desk** (Table 2). These six noun-noun phrases were used in the Interpretation Task, and in the Similarity and Dissimilarity Listing Task.

Word A	Word B	Category A	Category B
ship	box	non-wheeled vehicle	container
piano	guitar	musical instrument	musical instrument
desk	elevator	furniture	non-wheeled vehicle
drawer	plate	furniture	container
ship	guitar	non-wheeled vehicle	musical instrument
book	desk	manufactured item	furniture

Table 2: Noun-noun phrases used in the Interpretation Task and in the Similarity and Dissimilarity Listing Task

Next, two noun-noun phrases used for the Design Task were selected according to the following guidelines:

- Do not choose noun-noun phrases such that the same noun is included in the two noun-noun phrases.
- Do not choose a noun-noun phrase that can be interpreted as a commonly known phrase.
- Choose a noun-noun phrase that is suitable for a design task.

As a result, two noun-noun phrases—**desk-elevator** and **ship-guitar—**were selected.

Subjects

The subjects comprised 22 undergraduate and graduate students who were majors in industrial design. The subjects were divided into two groups: Group A (11) and Group B (11), in order to control the sequence effect of the tasks (interpretation task → design task; design task → interpretation task).

Experimental procedure

The experiment was performed using a booklet that included the task instructions as well as the answer sheets. This booklet consisted of instructions on the Interpretation Task, Interpretation Feature Enumerating Task, Design Task, Design Feature Enumerating Task, and Similarity and Dissimilarity Listing Task. Each group was assigned a different room and was presented with the tasks. We refrained from providing any oral instructions to ensure that the subjects realized the existence of two types of booklets to be used depending on the sequence of the tasks. The experiment was conducted as follows:

Step 1: Group A performed the Interpretation Task (1 min for each interpretation: total 6 min), while Group B performed the Design Task (10 min for each design: total 20 min).

Step 2: Group A performed the Interpretation Feature Enumerating Task (2 min for each interpretation: total 12 min), while Group B performed the Design Feature Enumerating Task (2 min for each designed concept: total 4 min).

Step 3: Group A performed the Design Task (10 min for each design: total 20 min), while Group B performed the Interpretation Task (1 min for each interpretation: total 6 min).

Step 4: Group A performed the Design Feature Enumerating Task (2 min for each designed concept: total 4 min), while Group B performed the Interpretation Feature Enumerating Task (2 min for each interpretation: total 12 min).

Step 5: Groups A and B performed the Similarity and Dissimilarity Listing Task (2 min for each noun-noun phrase: total 12 min).

In the Design Task, the subjects were asked to design a new concept; the designed concepts were evaluated on the basis of originality and practicality. On the other hand, in the Interpretation Task, they were required to naturally interpret the given phrases.

Method of Analysis

The responses obtained in the experiment were analyzed from the viewpoint of recognition types, thought types, creativity (originality and practicality), and the emergence of features. In this study, the emergence of the enumerated features was analyzed, while the design products were also measured by the evaluators from the viewpoint of originality and practicality. In order to accurately compare the design process with the interpretation process, only the responses to **desk-elevator** and **ship-guitar**, which were used in the Design Task, were analyzed.

Classification of the recognition types

We classified the design features and interpretation features and the responses to the Similarity and Dissimilarity Listing Task on the basis of the recognition types (commonalities and alignable and nonalignable differences) for the two nouns of the noun-noun phrase used in the Interpretation task (as well as the Design Task) according to the standards that were set by us in reference to those listed by Markman & Gentner (1993). The classification standards and examples are shown in Table 3.

	Classification standard and example
Commonality	When an identified feature refers to the common feature of concept A (or part of concept A) and concept B (or part of concept B) or is associated with both concepts Example: In the comparison between 'ship' and 'guitar', 'toy' was judged to be a commonality, since both 'ship' and 'guitar' can be toys.
Alignable difference	When an identified feature indicates a dimension and the values of each concept are different along the dimension, whether it is expressed explicitly or implicitly Example: In the comparison between 'piano' and 'guitar', 'how to play' was judged to be an alignable difference.

Nonalignable difference	When an identified feature refers to a feature associated with only one concept (or part of the concept) Example: In the comparison between 'ship' and 'box', 'vehicle' was judged to be a nonalignable difference.
Other	Cases that do not fall under any of the above three categories Example: In the comparison between 'ship' and 'guitar', the 'planter' was judged to be a feature that does not fit into any category.

Table 3: Classification standard of recognition types (commonality and alignable and nonalignable differences)

Classification of the thought types

The design product (sketch and sentence) and the interpretation were classified on the basis of the thought types according to the classification standard presented in Table 4; these were set up and used in our previous study(Taura, Nagai, Morita, and Takeuchi, 2007) in accordance with Wisniewski (1996). This classification was used to categorize the design products and the interpretation. Therefore, this classification is not actually based on the thinking process but on the result.

	Classification standard and example
Analogy	When the response is a type of concept B (A) similar to concept A (B) When a part of the property (shape) of concept A (B) or the concepts associated with concept A (B) is transferred into concept B (A) Example: In the design task of 'ship-guitar', 'ship-shaped guitar' was judged to be an analogy.
Blending	When the response has the properties of both concepts A and B, and it is neither concept A nor concept B When the response is related to concept A (B) from the viewpoint of the material, or the response is a part of concept A (B), and it has the property of concept B (A) Example: In the interpretation task of 'piano-guitar', the 'thing that is made up of clavier and strings' was judged to be blending.
Thematic relation	When the response stems from a situation in which concepts A and B are related to each other (e.g. A move to B) When the response is a type of concept B (A) that is made of concept A (B) When the response is a type of concept B (A) that is also meaningful with regard to concept A (B) Example: In the design task of 'ship-guitar', 'the guitar that plays

	well even on the moving ship' was judged to be a thematic relation.
Other	Cases that do not fall under any of the above three categories Example: In the design task of 'ship-box', 'ship' is judged to be a case which does not fit into any category.

Table 4: Classification standard of thought types (analogy, blending, and thematic relation)

Creativity evaluation

The creativity of the design products (sketch and sentence) were evaluated from the viewpoint of practicality (whether the idea seemed achievable and feasible) and originality (whether the idea was innovative and novel), based on Finke, Ward and Smith's (1992) creativity evaluation. Eleven raters evaluated all the design products on the basis of a five-point scale (1: low and 5: high). The rating scores were averaged for each design product. The design products with lower average scores for practicality than the overall average score for practicality were excluded from the creativity evaluation. For the remaining design products, the average scores for originality were considered as the measure of creativity.

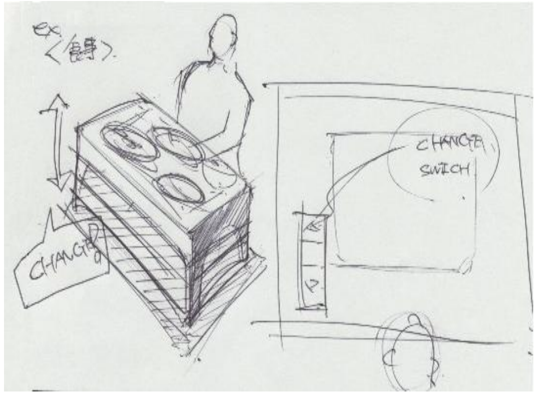
Judgement of emergent features

The enumerated features (interpretation features and design features) were judged as to whether or not they were emergent features by referring to Wilkenfeld and Ward (2001). When the feature was not found to be an associative concept of the two nouns (on the basis of which the interpretation and design tasks were conducted), it was judged as an emergent feature. Concretely, the associative concept dictionary (Ishizaki, 2006) and synonym dictionary (Yamaguchi, 2006) were used for this judgment. For each feature, when the feature was found to be an associative concept of the two nouns in the associative concept dictionary, it was judged to be a non-emergent feature. Furthermore, we investigated the synonyms of the associative concepts by using the synonym dictionary. When the feature was found to be a synonym of the associative concepts of the nouns, it was also judged to be a non-emergent feature.

Results

Seven responses (three for the Design Task, three for the Design Feature Enumerating Task, and one for the Interpretation Feature Enumerating Task) were excluded from the analysis because they were inadequate. First, we examined the influence of the sequence of the tasks. The results of a chi-square test were as follows: The proportions of the thought types of Groups A and B did not display a significant difference. For the interpretation and design tasks, the chi-square values were 0.96, n.s. and 0.24, n.s. respectively.

An example of the responses is shown in Figure 4.

<table>
<tr><th>Task / Phrase</th><th>Interpretation</th><th>Design</th></tr>
<tr>
<td>Desk-elevator</td>
<td>
(Response to the Interpretation Task)
An elevator to carry a desk, which is placed in a school. A person cannot get on the elevator. This elevator can carry many desks in less space.
(Thought type)
Thematic relation
(Enumerated Features and Recognition Type)
<table>
<tr><th>Feature</th><th>Recognition Type</th></tr>
<tr><td>object</td><td>others</td></tr>
<tr><td>school</td><td>commonality</td></tr>
<tr><td>place</td><td>commonality</td></tr>
<tr><td>carry</td><td>nonalignable difference</td></tr>
</table>
</td>
<td>
(Response to the Design Task)


A table that can be modified by replacing the surface with the upper and lower levels. Its structure is made up of levels such that each level can be used for dining, operating a computer, or reading a book. This type of table is useful for a person who would not like to use the same table for operating a computer and dining, and he/she does not have enough space for placing two tables.
(Thought type)
Analogy
(Enumerated Features and Recognition Type)
<table>
<tr><th>Feature</th><th>Recognition Type</th></tr>
<tr><td>button</td><td>nonalignable difference</td></tr>
<tr><td>flat</td><td>commonality</td></tr>
<tr><td>reading</td><td>nonalignable difference</td></tr>
<tr><td>change</td><td>nonalignable difference</td></tr>
<tr><td>level</td><td>commonality</td></tr>
<tr><td>switch</td><td>nonalignable difference</td></tr>
<tr><td>dining</td><td>nonalignable</td></tr>
</table>
</td>
</tr>
</table>

	difference
up and down	nonalignable difference
lunch box	nonalignable difference
interior design	nonalignable difference
personal computer	nonalignable difference

Ship-guitar

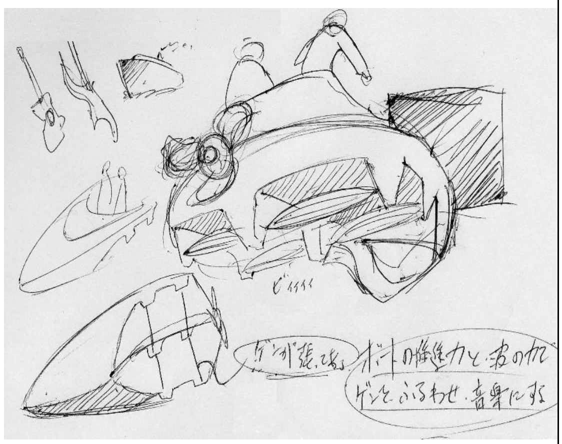
(Response to the Interpretation Task)
A guitar of the same scale as that of a ship. It can be used as a livery for a large town.

(Thought type)
Analogy

(Enumerated Features and Recognition Type)

Feature	Recognition Type
fragile	others
bright	others
large	nonalignable difference
object	commonality
coarse	others
inspection	commonality
base	others
long	nonalignable difference

(Response to the Design Task)



A guitar using a wave: The string of the guitar is plucked by the driving force of the boat and the waves of the water, resulting in a sound. This is a kind of boat that can be used as an instrument. This boat can be hired from a leisure center.

(Thought type)
Blending

(Enumerated Features and Recognition Type)

Feature	Recognition Type
leisure	commonality
live broadcast	nonalignable difference
reaction	others
sport	nonalignable difference

			exciting	commonality	
			resonance	nonalignable difference	

Fig 4. An example of the responses

Comparison of the design and interpretation tasks from the viewpoint of thought types

The classification of the design products (sketch and sentence) and the interpretation on the basis of thought types is illustrated in Figure 5. We found a high proportion of blending in the design products as opposed to in interpretation. This result corresponds to that of our preliminary experiment (Taura, Nagai, Morita, and Takeuchi, 2007) and reinforces the adequacy of hypothesis (1). The chi-square test detected a significant difference in the proportion of thought types between the two task types ($\chi^2(2) = 9.24$, $p < .01$). The result of the residual analysis indicated a significant difference in blending as shown in Table 5.

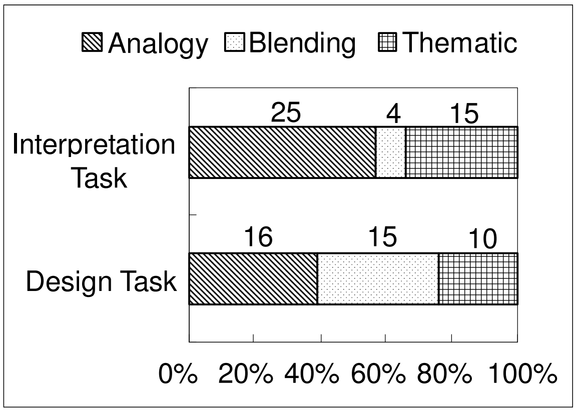


Fig 5. Classification of the responses according to the thought types

Thought Type	Analogy	Blending	Thematic relation
Interpretation Task	1.64	-3.04 **	0.98
Design Task	-1.64	3.04 **	-0.98

| residual | > 1.65 → † p < .10 ; | residual | > 1.96→ * p < .05 ;
| residual | > 2.58 → ** p < .01

Table 5: Result of the residual analysis for the classification of the responses according to thought types

Comparison of the design and interpretation tasks from the viewpoint of the recognition types (commonalities, and alignable and nonalignable differences)

According to the standard presented in Table 3, the interpretation features and design features were classified on the basis of recognition types.

The results are illustrated in Figure 6. In the chi-square test, a significant difference was detected in the proportion of the recognition types between the interpretation features and design features. ($\chi^2(2) = 4.69$, $p < .10$). The result of the residual analysis indicated that the proportion of nonalignable differences in the design features was higher than that in the interpretation feature, while the proportion of commonalities was low. It is assumed that more attention is paid to nonalignable differences in the design process than in the interpretation process, as shown in Table 6. This result is consistent with hypothesis (1).

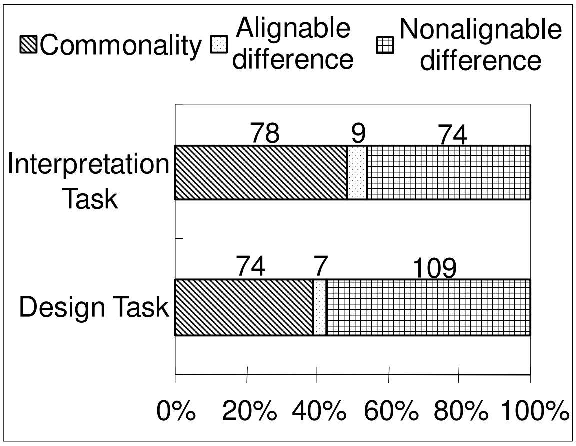


Fig 6. Classification of the responses according to the recognition types

Recognition Type	Commonality	Alignable Difference	Nonalignable Difference
Interpretation Task	1.79 †	0.85	-2.13 *
Design Task	-1.79 †	-0.85	2.13 *

| residual | > 1.65 → † p < .10 ; | residual | > 1.96→ * p < .05 ;

| residual | > 2.58 → ** p < .01

Table 6: Result of the residual analysis for the classification of the responses according to recognition types

Comparison of thought and recognition types

First, with respect to the interpretation features and design features, we determined the proportion of recognition types (commonalities and alignable and nonalignable differences) for each interpretation and design product. Further, we calculated the average of the proportions of the design products and interpretations classified under each thought type (analogy, blending, and thematic relation). The result is presented in Table 7. A two-factor factorial ANOVA indicated a significant difference in the factor of thought type with respect to the proportion of nonalignable differences ($F(2,76) = 3.22$, $p < .05$). This suggests that thought types may be characterized by nonalignable differences (Figure 7).

Table 7: Mean of the proportions of recognition types among the responses (classified by thought type) for the Interpretation Task and the Design Task (based on the Feature Enumerating Task)

Commonalities

	Analogy	Blending	Thematic relation
Interpretation	0.471	0.243	0.497
Design product	0.448	0.314	0.504

Alignable differences

	Analogy	Blending	Thematic relation
Interpretation	0.052	0.125	0.141
Design product	0.028	0.011	0.053

Nonalignable differences

	Analogy	Blending	Thematic relation
Interpretation	0.477	0.632	0.362
Design product	0.524	0.675	0.443

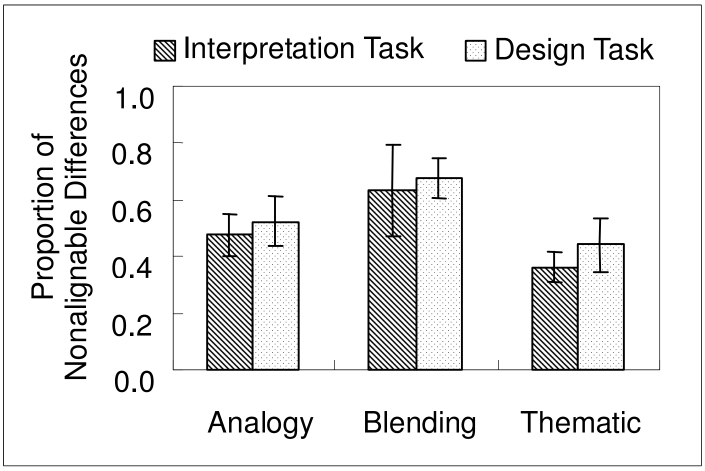


Fig 7. Mean of the proportion of nonalignable differences in the thought types for the Interpretation Task/Design Task (Feature Enumerating Task)

Note: The error bar shows the standard error of the mean.

In the analysis in the two preceding sections, it was found that blending and nonalignable differences characterize the design process. Confirming this finding, the result obtained above (Figure 7) suggests that nonalignable differences are related to blending.

Second, with regard to the responses obtained in the Similarity and Dissimilarity Listing Task, we determined the proportion of the recognition types (commonalities and alignable and nonalignable differences). Further, we calculated the average of the proportions of the responses belonging to each thought types (analogy, blending, and thematic relation); thought types were determined on the bases of the responses corresponding to the thought types of the design product and interpretation with respect to the same noun-noun phrase used in the Similarity and Dissimilarity Listing Task. It is assumed that this average indicates the manner in which things or concepts are viewed by the subjects whose design products and interpretations are classified under each thought types. The result is presented in Table 8. A two-factor factorial ANOVA revealed that there was no significant difference in the factors.

Table 8: Mean of the proportion of recognition type among the responses (classified by thought type) for the Interpretation Task and the Design Task (based on the Similarity and Dissimilarity Listing Task)

Commonalities

	Analogy	Blending	Thematic relation
Interpretation	0.392	0.775	0.41
Design product	0.39	0.451	0.405

Alignable differences

	Analogy	Blending	Thematic relation
Interpretation	0.205	0.133	0.186
Design product	0.249	0.163	0.117

Nonalignable differences

	Analogy	Blending	Thematic relation
Interpretation	0.403	0.092	0.405
Design product	0.361	0.386	0.478

This result suggests that focusing on nonalignable differences is not an inherent trait of the subjects (Figure 8); rather, it occurs during the design and interpretation processes.

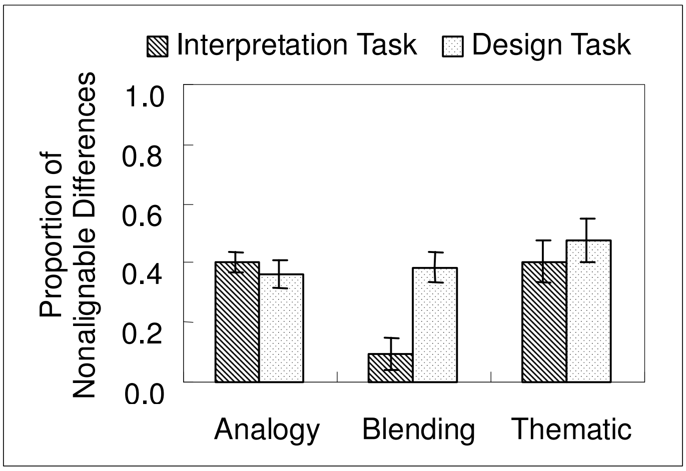


Fig 8. Mean of the proportion of nonalignable differences in the thought type for the Interpretation Task/Design Task (Similarity and Dissimilarity Listing Task)

Note: The error bar shows the standard error of the mean.

Comparison of the design and interpretation tasks from the viewpoint of the emergence of features

The mean of the emergent features (interpretation features and design features), which were judged according to the standard presented in subsection 3.4, is illustrated in Figure 9. This figure shows that more emergent features were used for explaining the design product rather than for explaining the interpretation (two-sided test: $t(82) = 2.36$, $p < .05$). This result indicates that more novel features emerge during the design process rather than during the interpretation process.

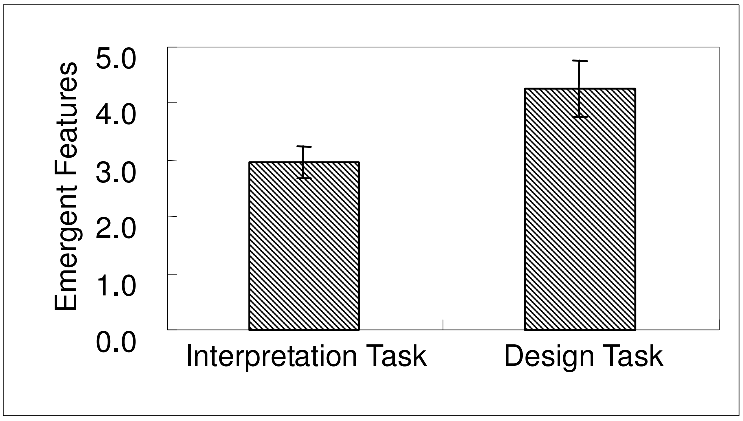


Fig 9. Mean of the number of emergent features

Note: The error bar shows the standard error of the mean.

Relation between creativity and recognition types

The creativity of the design product is evaluated according to the procedure determined in subsection 3.3. Kendall's coefficient of concordance shows a significant coincident factors in both originality and practicality (originality: $W = .34$, $\chi^2(40) = 148.86$, $p < .01$; practicality: $W = .32$, $\chi^2(40) = 142.18$, $p < .01$). Therefore, this evaluation result was used for the following analysis. The remaining design products had higher average scores for practicality than the overall average score for practicality: 9 (analogy), 6 (blending), and 4 (thematic relation).

No correlation between the originality scores the proportion of recognition type were detected (commonality and alignable and nonalignable differences) for any design products. However, a strong correlation was detected between the originality scores and the proportion of the commonality and nonalighnable differences for the design products classified into blending (nonalighnable difference: $r = 0.80$, $F(1,4) = 7.11$, $.05 < p < .10$, commonality: $r = - 0.80$, $F(1,4) = 7.11$, $.05 < p < .10$) (Figure 10).

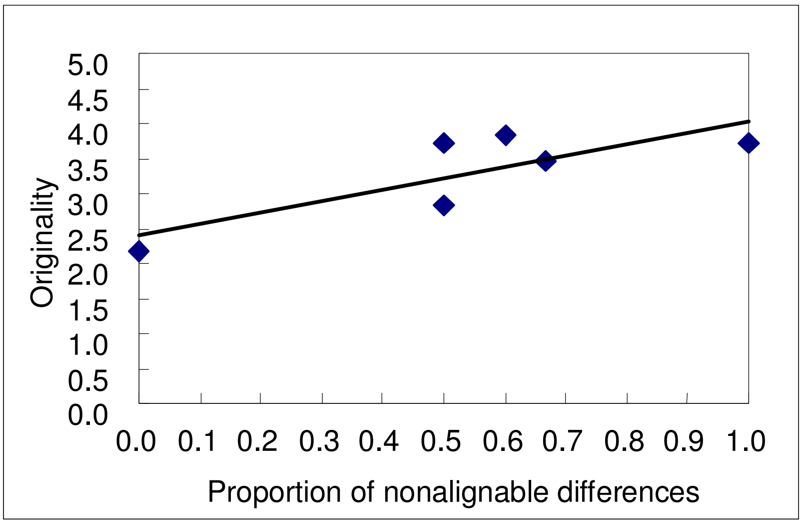


Fig 10. Relation between originality scores and proportions of nonalignable differences in blending

This result indicates that focusing on nonalignable differences is related to originality in concept blending, which characterizes the design process. This result is consistent with hypothesis (2).

Relation between creativity and the emergence of features

The relation between the number of emergent features and the originality scores is shown in Figure 11-13. A regression analysis detected a significant curve regression (R = 0.68, p < .01) rather than a linear regression. Furthermore, a regression analysis for the design products classified into analogy and blending detected a stronger significant regression (analogy: R = 0.82, p < .01; blending: R = 0.94, p < .05), while those classified into thematic relation did not indicate it. This result indicates that there exists an appropriate emergent level for inducing high originality in design.

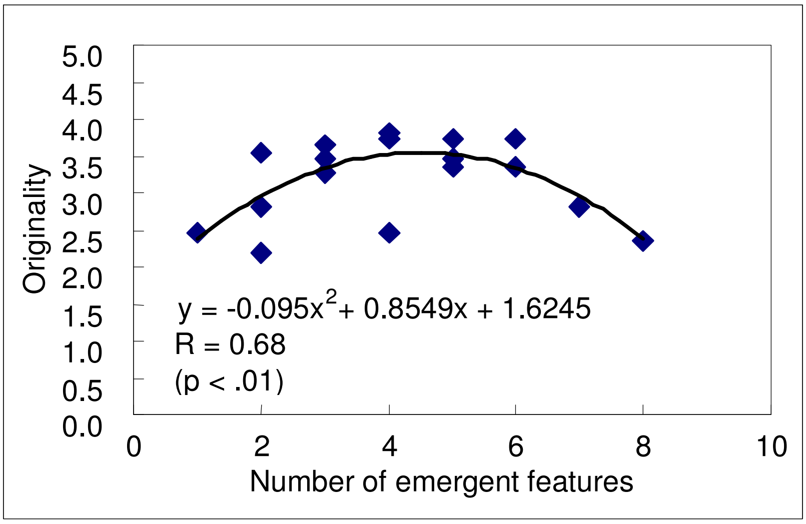


Fig 11. Relation between originality scores and number of emergent features

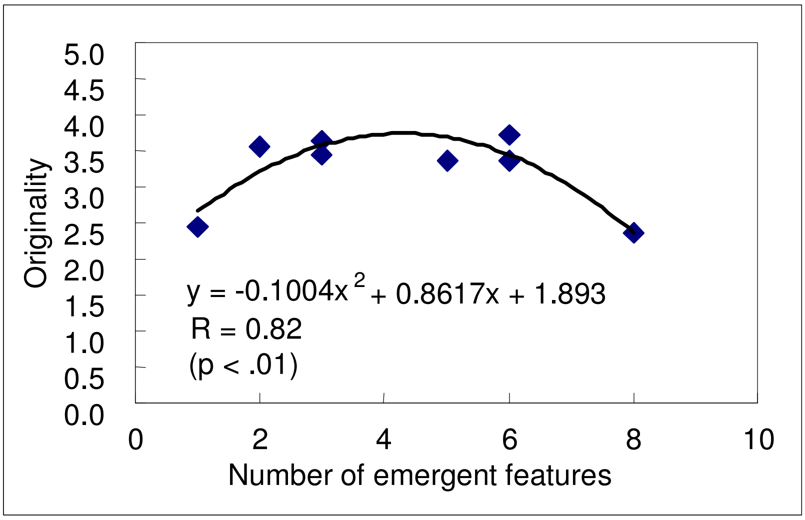


Fig 12. Relation between originality scores and number of emergent features in analogy

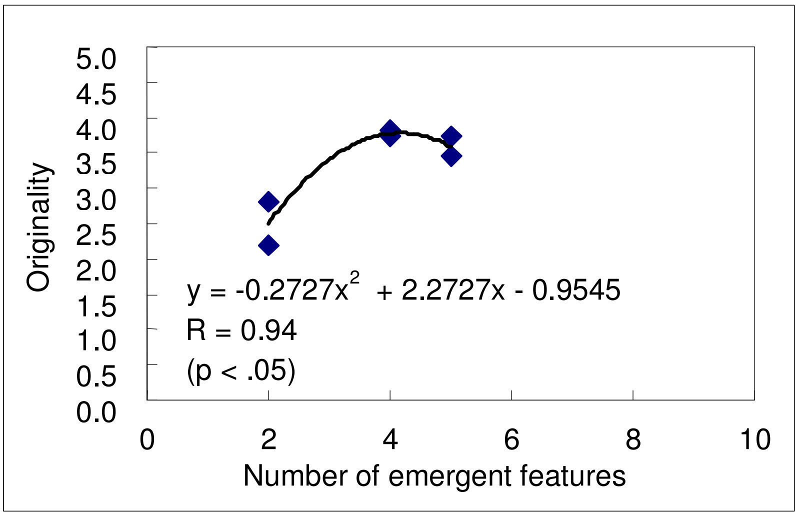


Fig 13. Relation between originality scores and number of emergent features in blending

Discussion

In the experiment, it was found that concept blending and nonalignable differences characterize the design process. With respect to the relationship between them, we assume the following models:

1. First, the designer captures the features of the two nouns (base concepts) from the viewpoint of nonalignable differences, and then adopts the concept blending process so that the nonalignable features are used.
2. Next, the designer attempts to adopt the concept blending process and then captures the features of the two nouns (base concepts) from the viewpoint of nonalignable difference so that the concept can be blended.

We are of the opinion that both the processes can co-exist, and the process adopted depends on the condition under which the designer is working. This issue is a problem to be discussed in the future.

Conclusion

In this study, we analyzed the characteristics of the design process in comparison with the interpretation process. In particular, we analyzed the characteristics from the viewpoint of the thought types (analogy, blending, and thematic relation) and recognition types (commonalities and alignable and nonalignable differences). Based on the analysis, it was found that blending and nonalignable differences characterize the design process. In addition, it was found that focusing on nonalignable differences is related to creativity in the blending process.

This research investigated the nature of the design process, in particular cognitive process in creative design. The findings of this research contribute to elucidate the details of cognitive processes underlying the creative design process, by focusing on the relations between thought types and recognition types. The results of the experiment this study reveal that both blending, and nonalignable differences characterize the creative design process. Therefore, the findings of this research indicate the kind of ability of recognition which should be taught in design education.

Probably, ability of recognition of nonalignable differences deeply relates to design abilities using the blending process. For example, we can consider how to encourage design students to use concept blending as a design practice, aimed at enhancing creativity. Given this, a framework of design education for fostering design creativity will be discussed. Moreover, this research contributes to knowledge about the creative design process and the characteristics of designers' creativity. The knowledge revealed not only for developing product design, but also for innovative design in any other domains, because concept formation is required, from the multi-disciplinary views of design creativity.

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