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An Analysis on Similarity of Product Images

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Abstract. Metaphor is based on the similarity of two things. It's the center of creative thinking. The purpose of this study is to understand humans' perception about similarity. This study uses Tversky's contrast model to discuss the similarity of product images with three issues: the importance of common features for similarity and dissimilarity; the asymmetry of similarity; the degree of similarity of two images in different context. Through three experimental investigations with chair and product images as material, different assumptions were tested respectively. The results show: (1) common features are more important while choosing similar source; (2) more salient images are regarded as a referent and comparison of similarity is asymmetry; (3) salience of features might be changed in different context. The results can be applied to metaphorical products and creative thinking to perceive common and salient fetures between different domains, and make a innovative connection.

Keywords: similarity, contrast model, product design, metaphor

1 Introduction

Metaphor helps the designer seek two different things to be integrated into a novel one during the earlier stages of design process(Casakin, 2007). Most of these scholars believe that similarity has significant meaning while comparing two objects, but they didn't discuss further by similarity. That makes us neither indistinct about concept of pictorial similarity, nor understand the cognitive situation while humans comparing two objects. Not only similarity is important for construct a metaphorical image but also the degree of similarity is a main factor for humans' perception. Thus, we thought it is necessary to explore humans' interpretation of product image by similarity.

Similarity is the basis of metaphor, and it also constrains the selection of particular linguistic expression to talk about something else (Kovecses, 2002). Similarity plays an important role in human perception (Melara, 1992; Tversky & Gati, 1978) and information organization and retrieval.

Previous models of similarity have its own weakness (Attneave, 1950; Shepard, 1964; Rorissa, 2007), like geometric/spatial, and assume humans pay equal attention to the various dimensions while judging similarity. Similarity can be measured until Tversky(1977) proposed contrast model.

Contrast model defines stimuli as sets of features and the similarity of any two stimuli as a linear function of a measure of their common and distinctive features. This influential model has provided a basis for inquiries into the nature psychological similarity and has been incorporated into models of other cognitive processes (Markman & Gentner, 1993). Many researches proved that contrast model is indeed helpful for comprehending similarity (Chan, 2000; Gati & Tversky, 1984; Johnson, 1986; Rorissa, 2007; Tversky & Gati, 1982).

The main purpose of this study is to understand humans' perception about the similarity of product images. According to Tversky's contrast model, we propose three issues that are: the relationship of judgments of similarity and difference; the direction of asymmetry of pictorial similarity; and the different context effects. We used three investigations to test whether the three issues can be explained similarity of product images, and used different images of chair and product as material to test different hypotheses.

2 Contrast Model

Tversky proposed a new approach, feature-matching, to define similar relationship of two objects. Two objects *a* and *b* are characterized by each set of features, denoted A and B, and the observed similarity of a to b denoted *s*(*a*, *b*). The observed similarity *s*(*a*, *b*) is expressed as a function which is composed by three elements: A∩B, the features hared by *a* and *b*; A－B, the features of *a* that are not shared by *b*; B－A, the features of *b* that are not shared by *a*. An interval similarity scale S preserves the observed similarity order, i.e., S(a, b) > S(c, d) if and only if s(a, b) > s(c,

d), that is, a and b are more similar than c and d are, and the function is given by:

$$S(a, b)=\theta f(A\cap B)-\alpha f(A-B)-\beta f(B-A) \quad (1)$$

θ, α, and β reflect weights given to the common and distinctive features and are non-negative (θ, α, β ≥ 0)

f is an additive function (that is, $f(A\cup B)= f(A)+ f(B)$), *f* is also an indicator of the salience of objects.

Contrast model posits that two stimuli are more similar if they have more common features and fewer unique features. Following sections are discussing more detail of contrast model in three parts.

2.1 Similarity and Difference

Let *s(a, b)* and *d(a, b)* denote ordinal measure of similarity and difference, respectively. Then *s(a, b)* is expected to increase with $f(A\cap B)$ and to decrease with $f(A-B)$ and $f(B-A)$, whereas *d(a, b)* is expected to decrease with $f(A\cap B)$ and to increase with $f(A-B)$ and $f(B-A)$. The relative weight of common and distinctive features may be different in different judging tasks because of the change in focus. In the assessment of similarity, the relative weight of common features is expected to be greater than in the assessment of difference.

Let us suppose the measure of similarity and difference are both symmetric to investigate this hypothesis, but with different weights of common features. Hence, the opposite situations are described as follow:

$$s(a, b)> s(c, e) \quad \text{iff} \quad \theta f(A\cap B)-f(A-B)-f(B-A) > \theta f(C\cap E)-f(C-E)-f(E-C) \quad (2)$$

and

$$d(a, b)>d(c, e) \quad \text{iff} \quad f(A-B)+f(B-A)-\lambda f(A\cap B) > f(C-E)+f(E-C)-\lambda f(C\cap E) \quad (3)$$

The weights of distinctive features can be equal to 1 in the symmetric case, then θ and λ reflect the relative weight of the common features in the assessment of similarity and difference respectively. If θ is very large, then the similarity ordering is determined by the common features. On the other hand, if λ is very small, then the difference ordering is determined by the distinctive features. Consequently, both s(a, b)> s(c, e) and d(a, b)>d(c, e) may be obtained whenever $f(A\cap B) > f(C\cap E)$ and $f(A-B)+f(B-A) > f(C-E)+f(E-C)$.

In sum, if the common features are weighed more heavily in judgments of similarity than in judgments of difference, then a pair of objects with many common and many distinctive features may be perceived as both more similar and more different than another pair (Tversky, 1977). This study would like to test if humans focus their attention more on common features when judging similarity than when judging differences of product images.

2.2 Directionality and Asymmetry

The similarity relation has been regarded as symmetry in geometric/spatial models to analysis similarity. Tversky (1977) argued that similarity should be an asymmetric relation. Similarity judgments can be represented by similar statement, i.e. the form "*a* is like *b*". This statement itself is directional. In this statement, *a* refers to a subject, *b* refers to a referent. It is not equivalent to the statement "*b* is like *a* ". Usually, humans tend to select the more salient stimulus as a referent, and the less salient stimulus as a subject. Hence, the asymmetry of similarity is determined by the relative salience of the stimuli.

If *s(a, b)* is interpreted as the degree to which "*a* is similar to *b*", then a is the subject of the comparison and *b* is the referent. In this statement, the features of the subject are weighted more heavily than the features of the referent (i.e., α>β).Thus similarity is reduced more by the distinctive features of the subject than by the distinctive features of the referent. If α>β, thus *s(a, b)> s(b, a)* whenever the distinctive features of *b* are more salient than the distinctive features of *a*(i.e., $f(B-A) > f(A-B)$) , or whenever *b* is more prominent than *a*.

s(a, b)> s(b, a) iff

$$\theta f(A\cap B)-\alpha f(A-B)-\beta f(B-A) > \theta f(A\cap B)-\alpha f(B-A)-\beta f(A-B) \quad (4)$$

iff $f(B-A) > f(A-B)$

Hence, under the contrast model and the hypothesis of α>β, the direction of asymmetry is determined by the relative salience of the stimuli, and the less salient stimulus is more similar to the salient stimulus. Although Tversky (1977) and Ortony (1985) proved the judgment of similarity is asymmetry, especially in simile (metaphor) statement, there still need a test with product images. According to this model, the task of judgment of similarity should be compared by two stimuli which one is more salient than the other.

2.3 Context Effects

The scale *f* is generally various with respect to changes in context or frame of reference. Namely, the salience of features may vary widely depending on implicit or explicit instructions and on the object set under consideration.

Tversky & Gati (1978) proposed the salience of features is determined in part of by their diagnosticity, i.e., classificatory significance. A feature may acquire diagnostic value in a particular context if it severs as a basis for classification in that particular context, then the value may become more salient.

When the context is extended by enlarging the object set, some features that had been shared by all objects in the original context may not be shared by all objects in the broader context. These features then acquire diagnostic value and increase the similarity of the objects that share them. Consequently, the similarity of a pair of objects in the original context is usually smaller than their similarity in the extended context. In other words, when enlarging the types of compared objects, the degree of similarity of a pair will become higher than in the context which is only one type. This study would like to test whether the degree of similarity of product images changes in different contexts.

3 Similarity of Product Images

3.1 Similarity versus Difference

The purpose of the experiment is to understand whether humans' judgments of similarity and difference of images affected more by common features and its relative weight.Based on the purpose, four hypotheses are formulated:

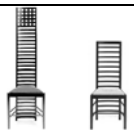
1. People attend more to the common features in judgments of similar images, i.e., images with more common features are considered more similar.
2. People attend more to the distinctive features in judgments of difference of images, i.e., images with more distinctive features are considered more different.
3. The relationship of similarity and difference are not complementary, i.e., $\theta>\lambda$.
4. Familiarity with images affects the choice of similarity or difference.

To investigate the relationship of similarity and difference, the material of this experiment is 20 sets of 4 images. Each set included two pairs of image of chair, one pair is classical or famous chair image, another pair is general or infamous chair image. The images of classical chair were obtained from textbook of design history and internet photos, while images of general chair from catalogs, magazines or internet.

The image choice follows these principles: similar appearance in the same pair, a designer's different products in different period, and the same series of products. A set is also composed by the same principle: similar appearance or property (armchair or stool) between famous and general pairs. These images were represented by gray to reduce the interference. The final material was completed after two preliminary tests to delete or amend the inappropriate image. For example, if the probability of a pair been selected as more similar or dissimilar is 100%, while the other pair is 0%, that indicated that the two pairs of images were not suitable for comparison in the same set, then the image should be removed or replace.

All subjects were presented with the same 20 sets in the same order. The famous pair(F) and general pair(G) within each set were arranged on the left side and right side randomly. Two groups of 18 subjects participated in the experiment. First, all subjects needed to select one pair of each set that is more famous. Then, one group of subjects- the similarity group- was asked to select one pair of chair images that are more similar in each set. Another group of subjects- the difference group- was asked to select one pair of chair images that are more different in each set.

Table 1. An example of experimental image

no	X	Y
14		

The steps of dealing with data described as follows: first, counting the number of times that two groups of subjects select, then converted times into percentage to get the percentage of each pair of similarity (Π_s) and percentage of difference (Π_d). (E.g. $F\Pi_s$ is the percentage of subjects who selected the famous pair in the similarity task.) If the percentage of a pair is higher than another in similarity group, that means the common features of this pair more than another, but more distinctive features in difference group. On the other hand, if $\theta>\lambda$, then the sum of two percentages would be greater than 100.

The result of statistic shows: the mean of percentage of 20 famous pairs in similarity task is 67.8%, which is over 50%. It can be explained that over half of subjects thought the famous chairs are

more similar than general chairs, and the difference is significant ($\chi 2=6.92$, $p<.01$). In other words, subjects perceived more common features of famous chairs than generals.

Sum up the Πs and Πd, the average value of 20 pairs of famous chair is 112.2, and the average value of 20 pairs of general chair is 87.8, the two value are not equal 100. The value of famous chairs is significant higher than 100 ($\chi 2 =4.03$, $p<.01$). The number shows image perception of similarity and difference are not fully complementary (i.e., $\theta \neq \lambda$; θ, λ presented the weight of common features in similarity and difference). In other words, one pair of images may be thought of more similar and more different at the same time in different comparison tasks, if they both have more common and more distinctive features.

Table 2. Percentage of famous pairs and general pairs in similarity group and difference group

no	Π_s (%)		Π_d (%)		$\Pi_s + \Pi_d$ (%)	
	F	**G**	**F**	**G**	**F**	**G**
1	61.1	38.9	38.9	61.1	100.0	100.0
2	72.2	27.8	50.0	50.0	122.2	77.8
3	66.7	33.3	27.8	72.2	94.5	105.5
4	44.4	55.6	77.8	22.2	122.2	77.8
5	72.2	27.8	27.8	72.2	100.0	100.0
6	61.1	38.9	38.9	61.1	100.0	100.0
7	77.8	22.2	38.9	61.1	116.7	83.3
8	66.7	33.3	55.6	44.4	122.3	77.7
9	72.2	27.8	55.6	44.4	127.8	72.2
10	61.1	38.9	33.3	66.7	94.4	105.6
11	83.3	16.7	33.3	66.7	116.6	83.4
12	66.7	33.3	38.9	61.1	105.6	94.4
13	44.4	55.6	44.4	55.6	88.8	111.2
14	77.8	22.2	61.1	38.9	138.9	61.1
15	66.7	33.3	55.6	44.4	122.3	77.7
16	72.2	27.8	33.3	66.7	105.5	94.5
17	83.3	16.7	22.2	77.8	105.5	94.5
18	77.8	22.2	44.4	55.6	122.2	77.8
19	50.0	50.0	61.1	38.9	111.1	88.9
20	77.8	22.2	50.0	50.0	127.8	72.2
	67.8	**32.2**	**44.4**	**55.6**	**112.2**	**87.8**

The value in Table 2 shows 6 pairs of famous chair be perceived both more similar and more difference, especially the well-known chair, like Mackintosh's "Hill House Chair". These results demonstrated not only Tverksy's argument, $\theta>\lambda$, but that the relative weight of the common and the distinctive features vary with the nature of the task.

The researchers further discuss whether familiar with images would affect the choice of similarity or difference by chi-square test. The result of testing shows that subjects thought the famous chairs are more similar, while they were familiar with the famous pair. On the other hand, if subjects were not familiar with the famous pair, they thought the famous chairs are more different ($\chi^2 =5.45$, $p<.05$). However, in some sets, ever the subjects chosen the more famous pair correctly, most of them still selected that the general pairs looks more different. Unlike text materials (Tversky used country), the appearance/shape of product image affects subjects' judgment of difference is obviously important than prominence of image. In other words, subjects accept more concrete information while perceiving image than in text, because they judge similarity or different by visual sensor directly.

Conclusion, famous chairs are perceived more common features (more similar) than general ones. The relative weight of the common and the distinctive features vary with the nature of the task ($\theta>\lambda$), and people attend more to the common features in judgments of similarity than in judgments of difference.

3.2 Asymmetry of Similarity

The goal of this experiment is to understand the asymmetry of judgment of image similarity. We assume one is referent, another is subject, and one is more salient than another (i.e., $\alpha>\beta$), then *s(a, b)*>s*(b, a)*.

Hypotheses of this study as follows:

1. Human access the similarity of images is asymmetry, and the more famous image is chosen to be a referent.
2. The degree of similarity of images is different while accessing the relationship between "*a* is similar to *b*" or "*b* is similar to *a*".

The material of this study is 21 pairs of chair image composed of 21 famous chairs and 21 general chairs. The images of famous were obtained from classical designer's chair of design history textbooks, generals were obtained from catalog or internet. The more famous is named to *b* sets, general chairs is *a* sets. The 21 pairs of image were arranged by the principle of

similar appearance. Final images for experiment were modified after pilot study and checked by designers.

The participants are two groups of 28 students, and procedure of the experiment is two steps. First, we want to know which of two images would be chosen for referent, all participants were asked to select which of the statement they prefer more: "*a* is similar to *b*" or "*b* is similar to *a*". Secondly, one group was asked to assess "the degree to which famous chair is similar to general chair," whereas the other group was asked to assess "the degree to which general chair is similar to famous chair."

Table 3. An example of experimental image

no.	a	b
6		

In the first part, we used percentage to present the selection of participants. The percentage of "*a* is similar to *b*" shows in Table 4. If the percentage is higher, that means participants were more prefer to one of statements. As we can see, most of participants prefer similar statement of"general chair is similar to famous chair" (χ^2 =4.87, p<.01). In other words, the more famous or salient image would be regarded as referent.

Then, we want to further verify whether the degree between "*a* is similar to *b*" and "*b* is similar to *a*" is different. After calculating the score of two statements in all 21 pairs, the degree of "general chair is similar to famous chair (5.95)" are significant higher than the degree of "famous chair is similar to general chair (4.45)" (t=5.33, p<.01), so that s(a, b)> s(b, a).

Conclusion the above result, participants may select one of images as referent while comparing the similar relationship, and prefer the classical designer's chair as base. The main reason is classical or designer's chairs are more well-known, participants are more familiar with them. On the other hand, classical chairs are more aesthetics than general, and easy to catch the attention of participants. In other words, the classical chair is regarded as more salient, so the probability as a referent is higher.

The comparison of similar images is not only the definitely referent, but the degree of similarity is obviously different. The main reason is the reputation and influence of classical chair is more than generals, participants may have a thought that general chair is imitated from the classical. That's why the degree of "famous chair is similar to general chair" is relative low. The result proved that direction of similarity of images is asymmetry.

Table 4. The asymmetry and mean of percentage of similarity of 21 pairs of chair image

no	a is similar to b (%)	s(a, b)	s(b, a)
1	83.9	5.07	4.29
2	51.8	4.54	3.14
3	28.6	4.07	3.29
4	67.9	3.46	2.54
5	87.5	6.29	4.32
6	73.2	8.00	5.86
7	51.8	5.43	3.86
8	64.3	4.46	3.50
9	41.1	8.29	6.57
10	89.3	7.07	5.29
11	75.0	7.68	5.96
12	91.1	4.93	3.93
13	57.1	5.71	3.89
14	80.4	6.86	5.57
15	92.9	7.61	5.43
16	44.6	6.21	4.64
17	83.9	4.86	3.79
18	80.4	5.79	4.36
19	82.1	5.14	3.36
20	78.6	5.50	4.00
21	55.4	8.07	5.93
Mean	**69.6**	**5.95**	**4.45**

3.3 Context effects

The salience of features varies with different objects under consideration or classifications which object belongs to while comparing two similar images, and affects the degree of similarity between images. The hypothesis of this study is: the similarity of a pair of images in the original context is usually smaller than their similarity in the extended context.

The materials were composed of two sets of product image, one brand is Alessi from Italy, and another is Georg Jensen from Denmark. Each set contained eight pairs of two images which their appearances are similar. The purpose is to test the degree of similarity would be higher in blending set; the materials were divided into two sets: homogeneous set(Ho)and heterogeneous set (He). The heterogeneous

set were listed by crossing the images of brand A and G, so that the list of 16 pairs that participants received was A1－G1—A2—G2－……－A8－G8. The list of homogeneous set was arranged in order by individual brand.

Table 5. An example of one pair of brand A and G

Brand A	Brand G
	

Two groups of 27 participants were asked to assess the degree of similarity of each pair with the scale from 1(minimum similarity) to 9(maximal similarity). The group of homogeneous took 10 minutes rest to reduce the interference between two image sets during testing, whereas the group of heterogeneous was presented by all 16 pairs in a row.

The average similarity for each pair of images obtained in the homogeneous and the heterogeneous contexts, denoted So and Se, respectively, are presented in Table 6. The average difference between Se and So is 0.66, and the difference of these score is significant ($t=3.50$, $p<.01$).

The result of this study demonstrated that the similarity of images which participants perceived changes with different images under consideration. When a product image is sited by an image with similar style, participants would not focus on the similarity only. Image is contained many elements, even the pair of images with the same style, there are still some difference among the elements. Participants perceived the similarity and difference at the same time, so the salience of features was decreased. That's the reason why the degree of similarity is lower in homogeneous set.

Participants, however, were focus on the difference between pair and pair, while the comparison of images composed of two different styles of product images. In this situation, not only compared the similarity of the two images of one pair, they also affected by the different style of product images next to what they were assessed. In other words, participants noticed every pair is different to each other, the context effects, that result in they felt the two images of each pair are more similar than they thought. Because the salience of some features becomes more prominent, the degree of similarity in heterogeneous set is higher than homogeneous set. The result supports the hypothesis of this study that function f changes with different images under consideration.

Table 6. The average of similarity of Ho and He

Ho	So	He	Se
A1	4.22	A1	4.33
A2	4.00	A2	4.60
A3	3.52	A3	4.47
A4	7.30	A4	7.40
A5	5.93	A5	5.00
A6	2.89	A6	4.07
A7	5.67	A7	6.20
A8	5.19	A8	5.73
G1	5.52	G1	4.80
G2	4.15	G2	5.07
G3	5.74	G3	6.47
G4	4.63	G4	6.27
G5	5.89	G5	6.47
G6	4.89	G6	6.13
G7	3.70	G7	4.93
G8	4.07	G8	5.87
Mean	4.83	Mean	5.49

4 Conclusion

Metaphor is a creative method that finds and constructs the similarity between objects in two different domains. The purpose of this study is to understand the circumstances about humans comparing the similarity of product images. When humans observe one object or product, this entity will be dismantled into several different characteristics, like attribute listing, to observe one object through elements or features analysis. When comparing two objects, whereas, humans would notice the common features of them. The result of exp.1 apply to product design, that is a designer find some common features of two stimuli belong to different domains, and perceived the similarity that unconscious by other designer, the combination of these stimuli will be a innovation.

No matter the design education or practice, the assessment of similarity is used widely; to develop the ability of perceived the common elements of entities in the same classification at initial step of design exercise. Then, to develop the ability of compared the common features of objects in different classifications gradually. Further, to design an innovative product by

design method: metaphor. The selection and application of salient features is the important point while a designer expresses the character of a product.

The result of experiment 2 applied to design education or practice, to help designers consider the familiarity or reputation of source while designing a product. The strength of a famous source make new product not to strange for customers, because customers would associate the sharp, function or symbol of new product with source. Constructing the similar features for product identification and brand imagination is an important key point.

The degree of similarity of an object changes with different context. Applying the result of experiment 3 to design education or practice, a designer have to compare several sources, and select a similar source which expresses the design concept and features best to make the design more persuasion.

To sum up the result of this study, we suggest the principles of creating and evaluating a metaphorical product:

2. Two objects must have enough common features which can be perceived.
3. Using prominent or familiar things as source, and make the direction of similarity being asymmetry.
4. Choosing a suitable source make the features of product more salience.
5. Expressing the product by highlight the features of source to make the asymmetry more obvious, thus, the metaphoricity of product will be more salient.

These principles can be used to create a new design by connecting similarity between different domains.

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