A Study on the Cognitive Thresholds of Formal Styles

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Abstract: Formal styles have been recognized as an effective marketing segmentation marker for differentiating various preferences among consumer groups. In recent years, research that focuses on mapping the relationships between consumers' Kansei feelings and products' formal elements has become a hot topic in design fields. However, how consumers differentiate one particular product form style from the other is still vaguely understood. The objective of this study is twofold: (1) to search for and verify the range of cognitive thresholds for formal styles and (2) to construct a formal language for better describing formal styles, through scientific processes and such techniques as semantic differential analysis and fuzzy sets theory. To achieve the objective, two experiments are conducted in this study. The first experiment gathers raw data via performing semantic differential analysis on a series of well-perceived-style products by experienced designers. The data gathered are then converted and fine-tuned using fuzzy sets theory to verify the range of cognitive thresholds of formal style. In the second experiment, three products with three different formal styles are used to further investigate the critical elements contributing to the cognitive thresholds for each style. The results suggest that: (1) the cognitive thresholds of formal style do exist; (2) the range of cognitive thresholds of a formal style depends largely on its formal consistencies; and (3) the critical elements vary with different formal styles.

Key Words: formal style, formal language, form element, cognitive thresholds, Kansei engineering.

1. Introduction

Conventionally, how to achieve the set goals for design problems, especially with the aid of modern computer technologies, has been a dominant topic in design research. However, the research on what should be designed in regard to functionality, usability as well as personal tastes has just become a recognizable area in recent years. In this regard, several techniques and methods, such as Kansei engineering, fuzzy sets theory, semantic differential method, and multidimensional scaling, etc., have been proposed to help identify or extract both users' physiological and psychological needs and wants.

Communicating a design with its users or among designers, through systems or products, involves the cognition and positioning of the formal styles it conveyed. Products satisfy consumers' needs in expressing themselves through formal styles. A good design, hence, is meant to be able to communicate consumers' tastes via product's form elements. Therefore, a designer should understand what consumers' tastes really are before he/she could talk fluently in his/her formal language. However, how consumers differentiate one particular product form style from the others is still vaguely understood. Form elements, joining relationships, detail treatments, materials, color treatments and textures, and many others, are believed to be the factors in forming a product's formal style [6]. Nonetheless, how these factors interact in making one particular style instead of the other needs to be further studied. As for style cognition, there were as many theories suggested as the definitions of style. Chan [4] suggested that the topological structure among stylistic features is the most important factor for sustaining a style while geometrically distorted features (up to ~40%) are still recognizable. However, Chan [4] also pointed out that the value of the degree of distortion varies among features, and is basically determined by the beholders' perceptions.

Based on these understandings, in this study, the authors tried to (1) search for and identify cognitive thresholds for formal styles and (2) construct a formal language for better describing the formal styles by setting up scientific experiments incorporating such

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techniques as semantic differential and fuzzy sets theory. It started by testing the range of cognitive thresholds of formal style by employing fuzzy sets theory to convert data which were gathered via a semantic differential method based on a series of products with well-perceived style, i.e., Bauhaus in this case, as samples. Subsequently, three products with different formal styles were used in the second experiment for further exploring the critical constructing elements among different formal styles.

The next section reviews some literature in related fields. Section 3 describes the cognitive threshold model to be used for conducting two experiments. In Section 4, the first experiment that tests the range of cognitive thresholds via different products with the same style will be depicted. After that, in Section 5, the second experiment that verifies the constituent elements of cognitive thresholds via products with different styles will be described. The last section (Section 6) summarizes the main conclusions reached in this work.

2. Related Studies

2.1 Formal Styles

Stated by Dondis [10], 'Style is the visual synthesis of the elements, techniques, syntax, inspiration, expression, and basic purpose.' Formal style inherits various definitions and meanings from style alone. After reviewing both the historical development of style in fine arts and the concepts of style in forms of products, Chan [3] proposed three assumptions following her operational definition of style, namely, (1) a style is caused by the act of repetition, (2) a style arises from choices, and (3) a style arises from search efforts. Chen [6], on the other hand, concluded that the only way to completely capture the essence of formal style was via systemic analysis, in which its functions, structure, and components should be examined. According to Chen's research, formal style serves four functions, viz. classifying, attributing, expressing, and stimulating. Its structure has the nature of being hierarchical, componential, and independent; and components comprise two major categories, formal elements and stylistic features.

2.1.1 FORMAL ELEMENTS

The basic elements of a product, from a spectator's view, include the solids constituting the product's body, any graphics on the surface, materials used in construction, colors, and textures. These give physical properties of an object. A style can be expressed through a unique composition and configuration of these elements. Dondis [10] suggested a list of 10 visual elements used in basic two-dimensional graphic designs, viz. dot, line, shape, direction, tone, color, texture, dimension, scale, and movement. Bowman [2] limited his form vocabulary to five elements: point, line, shape, value, and texture; others appear at higher levels of his space grammar or perspective idiom.

Other definitions of formal elements vary. In Pile's *Dictionary of 20th-Century Design* [14], 'The form of a thing involves its shape, color, texture, ornamentation, and every other aspect of its physical reality.... The term 'visual form' is also often used to help define the concept of form and limit it to the qualities of an object that can be seen.'

2.1.2 STYLISTIC FEATURES

The words used to describe psychological feelings about a product are abundant, e.g., sharp or dull, heavy or light, balanced or unbalanced, smooth or rough, etc. Osgood et al. [13], in *The Measurement of Meaning*, first utilized polar adjective pairs to measure the meaning of fuzzy words. These pairs can further be grouped into categories, such as valuation, potency, activity, etc. Dondis [10] used such pairs as balance–instability, symmetry–asymmetry, simplicity–complexity, etc., to describe qualities for visual communication. Also mentioned in Dondis' [10] are three levels for expressing a visual message, viz. representation, symbolism, and abstraction. Again, these can be transformed into polar adjective pairs and used as stylistic features.

Conventionally, form is a term used to describe general shape, structure, design, appearance, and type, etc., while style is used to describe the distinctive quality of a shape, structure, design, etc. In other words, only those objects that have distinctive qualities have style, while all objects have form regardless of whether they have style or not. A style can be said to have or need a form to present its visible appearance. These two concepts, i.e., form and style, even without one-to-one mapping relationships, could be integrated within a framework formed by two axes representing formal elements and stylistic features, respectively. Any describable stylistic features can then be mapped to a series of formal elements and be located within this form–style space.

2.2 Style Recognition

Formal style is a key factor differentiating consumer markets. According to Doblin [9], some high level discriminators (e.g., Gropius, Moholy–Nagy, Mies van der Rohe, Eames, Vignelli, Chermayeff, Rand, Nizzoli, Bill, Rames, etc.) have the ability to both recognize styles and think in systems. Nevertheless, how exactly people (including the above figures) perceive a so-called 'X style' was not much explained. However, some theories established in other fields, such as Gestalt psychology and cognitive psychology, in explaining the way people recognize shapes may have pointed to a relatively promising direction for this purpose.

Being able to recognize shapes or patterns is one of a human's most basic instincts. Through recognition, man can differentiate things and/or objects and make further categorization and remembrance possible. Such kind of recognition ability is believed to be both sophisticated and constant; which means that things and/or objects can still be recognized without a problem even when their physical appearances vary dramatically. Hence, it is believed that all formal styles consisted of a particular set of stylistic characteristics that can still be recognized under different physical structures. Chan [4] concluded that a style is represented by a common set of features that appear in objects, and is measured by the number of features present in a given set of artifacts. Some other theories are reviewed and analogized in parallel as follows.

2.2.1 GESTALT GESETZ

Early Gestalt psychologists have summarized several human perceptional phenomena, viz. proximity, similarity, continuation, closure, simplicity, symmetry, and common fate, according to the way people recognize shapes [1]. Since formal styles cannot be perceived without visible images and shapes, which are the very basic elements of all sorts of images; therefore, some discoveries made in Gestalt psychology might have a meaningful parallel association in explaining the way people recognize formal styles.

2.2.2 TEMPLATE-MATCHING THEORY

People learn and experience formal styles in all sorts. In the template-matching theory of cognitive psychology, it can be considered that each time a new style comes to a person's mind it forms a template; therefore, one can have many such templates in one's memory. The whole process can be comprehended as follows: a formal style is identified first; and then, it is recognized as a new kind and stored as a template in a person's memory if it does not match any of the templates already saved in his memory; otherwise, it will be recognized as the style of the template it matches and associated with it. Although it may not seem so practical for people to remember all the formal styles template-by-template, however, obviously it does offer a schematic framework, i.e., templates, for people to save information about formal styles with a unique set of stylistic characteristics.

2.2.3 PROTOTYPE THEORY

A human's visual experiences also indicate that some forms do share the same set of visual characteristics among each other. People tend to recognize these forms as a unique style according to the common visual characteristics they share. Such a set of common visual characteristics, which specifies a particular style, is deemed as the norm or the prototype of a given style. Two models can be identified: (1) central tendency model, which considers the prototype as the average representation of many samples; and (2) attribute–frequency model, which considers the prototype as the sum of attributes that are most frequently sensed. Moreover, the recognition processes, which use the norm as a matching-aid, are, therefore, grouped into the class of prototype theory.

2.2.4 FEATURE ANALYSIS THEORY

Feature analysis is a very important process within information analysis. Features are considered as the basic distinct attributes, which can be applied to tell one shape from the other. Formal style, regarded as the qualitative information a product carries, can only be perceived and categorized properly through comprehensive analysis of its complicated structure. Therefore, the features or attributes a certain style has can be identified and then used for differentiating products with different visual characteristics.

2.2.5 SUMMARY

Through the review and parallel analogy of the related theories established in the fields of Gestalt psychology and cognitive psychology, such theories as Gestalt gesetz, template-matching, prototype, and feature analysis are found useful for understanding the processes of formal styles recognition. Chen [5] summarized that formal styles depend basically upon physical form-properties and psychological imagery-effects. This particular remark is coincident with the aforementioned theory of feature analysis and will underpin the proposed framework used to test the cognitive thresholds in this study.

2.3 Thresholds

Threshold is defined as 'the point at which a stimulus is just strong enough to be perceived or produce a response' in Webster's dictionary [11]. In other fields, the definition follows in a similar pattern: the minimum energy (in physics), additive (in chemistry), or stimulus (in physiology) required for making an effect, producing a reaction or intriguing a sensation, respectively. In the field of human factors engineering, threshold is differentiated into two types, absolute threshold and difference threshold [17].

2.3.1 BASIC CONCEPTS

As mentioned earlier, in the field of human factors engineering, the two important indicators for measuring the minimum extremes of human sensory functions are absolute threshold and difference threshold. The former is defined as the minimum physical energy required by a sensorium before any sensory experience can be intrigued, while the latter as the minimum difference that could be sensed between two stimuli.

Absolute threshold varies among individuals. It even varies between different time periods for the same individual too. According to a psychologists' definition, an absolute threshold is the stimulus intensity that can be sensed at about 50% of the time it applies to the sensor. On the other hand, a difference threshold is the difference between standard stimulus and comparison (or variable) stimulus, if and only if the two stimuli are sensed to be the same or not the same for about 50% of the times tested. Therefore, it is also called 'just noticeable difference.'

2.3.2 CONFIDENTIAL REGION

The confidence coefficient of the confidential region is frequently used to check the reliability of the sample data statistically. In order to avoid any decision related risk caused by human misjudgment, a hypothesis of rejected probability is often used as a measuring standard. The range of values falling within the check standards is called the confidential region (or accepted region); and the one outside the check standards is called the rejected region (or critical region). The demarcation points that divide the two regions are called critical values, which are frequently used in the hypothesis validation and/or standard normal distribution. There are three types of statistically rejected regions: single-sided upper, lower tails, and double-sided values [8].

In dealing with fuzzy phenomenon, other than the above-stated critical values used in treating random phenomena, a cutting set (also known as thresholds) is used for judging membership in fuzzy sets theory, in which, the membership value is $\lambda(0 \le \lambda \le 1)$ and $A\lambda = \{X | \mu A(X) \ge \lambda\}$ is the cutting set of fuzzy set A. Thus, X belongs to A and, when $\lambda \le \mu A(X) \le 1$, X belongs to $A\lambda$ too [16].

In summary, 'threshold' has been considered as a distinctive value in making a judgment for quantitative research in various disciplines. In much the same way, it can be employed to tell the subtle variation in formal styles for the design professions.

3. A Proposed Framework for Differentiating Formal Styles

Many researchers have tried to unveil the black-boxed manipulations of formal styles. Among them, Shaw [16] used stylistic elements as control variables to explore the affected scope for each single stylistic element through analyzing the stylistic elements of Ming-styled chairs. Lin [12] summarized the elements affecting a product's identity via employing a multidimensional scaling method. Yeh [18], on the other hand, proposed a mechanism for the conversion between colors and imagery words by adopting the membership function and approximation of fuzzy sets theory. The main purposes of these studies were to figure out the dominating factors of certain styles in order to assist designers reproducing inferred styles for new products.

In this work, both the concepts of pattern recognition from fuzzy sets theory and the concepts of the style profile from Chen and Owen [6] were used as the basis for the construction of a general model and the setting of cognitive thresholds for describing and positioning a product formal style. The model was designed as an open universal framework capable of describing any formal styles; while the cognitive thresholds were being set to define particular product formal style as well as guide the creation of its sibling styles.

3.1 A Model for Describing Formal Styles

Saussure [15], in differentiating language system into langue and parole, pointed out that what formed meanings were not the sounds themselves but the distinctions between each of them. As the relations between signifiers and signified are arbitrary, they are purely relational entities, or differential entities, as Saussure put it. By the same token, the formal style (viewed as formal language) system can also be divided into formal signifiers (e.g., style labels or Kansei words, etc.) and the imagery signified (e.g., style images or formal elements, etc.). As such, in order to be able to tell which product is of what style, one must identify and distinguish the relations between Kansei words and formal elements for each formal style of interest.

Facing a particular product's formal style, one must fully understand its formal elements before being able to completely master it and differentiate it from others. In this respect, Chen and Owen [6] proposed six major formal elements, viz. form components, joining relationships, detail treatments, materials, colors, and textures. Nevertheless, the key is that, as stated above, the formal elements themselves do not form a unique style but the difference presented among different styles does.

By combining Chen's Style Profile [6] with Bauhaus' stylistic features, a framework is formed as shown in Table 1. The framework contains five adjective pairs chosen for describing form components used in Bauhaus style; three adjective pairs for joining relationships; four adjective pairs for detail treatments; five adjective pairs for materials; five adjective pairs for colors; and another five adjective pairs for textures. As aforementioned, the proposed model is an open framework. Formal elements as well as adjective

Table 1. A framework for describing formal styles.

Formal elements	Polar adjective pairs
Form components	Harmonious–contrasting
	Geometric–biomorphic
	Pure–impure
	Simple–complex
	Balanced–unstable
Joining relationships	Monolithic–fragmentary
	Self evident–hidden
	Static–dynamic
Detail treatments	Uniform–multiform
	Angular–rounded
	Functional–decorative
	Subtle–bold
Materials	Harmonious–contrasting
	Single–multiple
	Hard–soft
	Smooth–rugged
	Mat–glossy
Colors	Harmonious–contrasting
	Single–multiple
	Bright–dark
	Cool–warm
	Soft–hard
Textures	Harmonious–contrasting
	Single–multiple
	Subtle–bold
	Regular–irregular
	Tactile (3D)–visual (2D)

pairs can be adjusted according to specific style of interest in order to better describe its stylistic features.

3.2 The Fuzziness and Overlapping of Cognition Profile Ranges

While identifying a specific style, one usually searches for its particular stylistic characteristics based on his/her personal understanding and subjective feelings about that style. As such, everyone may have a different mental image about a very same style. Nevertheless, it does not necessarily mean that knowledge of people about style is not reliable, but rather reveals the fuzzy nature of a stylistic image and the various ranges of cognitive thresholds. Figure 1 depicts a normal distribution range of a stylistic image, while Figure 2 shows the overlap of the two stylistic images. In the case exhibited in Figure 2, one can easily differentiate between two styles when there are more stylistic characteristics with separable regions (shown as Xa and Ya); however, it would be harder to tell one style from the other while there are more overlapped regions (shown as XYc).

In the experiments presented in Sections 4 and 5, the authors first tested out the range of cognitive thresholds with different products of the same style, and then verified the constituent elements of the cognitive thresholds with products of different styles.

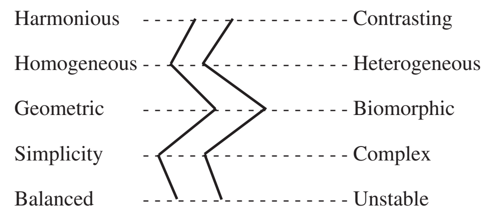

Figure 1. Cognition profile range of style X.

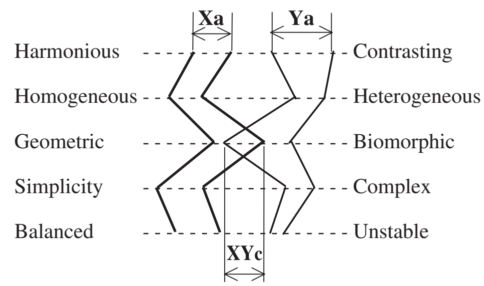

Figure 2. Two styles in comparison.

4. Experiment I

4.1 Purpose

To test the range of cognitive thresholds.

4.2 Samples Used

For a better coverage of the range of Bauhaus style, 10 different products (slides) were chosen as experimental samples (see Figure 3).

4.3 Subjects Selected

Sixty five (65) subjects, consisting of both undergraduate and graduate students, were selected for this experiment – 37 males and 28 females.

4.4 Instruments Used

A slide projector, 10 slides, and a predesigned questionnaire were used. Photos echoing each slide were also put on the questionnaire, and a seven-point scale was used in the questionnaire.

4.5 Procedure

The experiment was carried out in groups in a 50 min session, and the procedure was divided into three consecutive steps as follows.

1. The tester explained to the testees the purpose of the experiment, technical terms as well as the means of filling out the questionnaire. This step took 8 min.

Figure 3. The 10 experimental samples of Bauhaus style.

Table 2. Data counts and percentages on 'Harmonious–contrasting' for the ten products.

	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Product 1	0 (0)	2 (4.1)	14 (28.6)	5 (10.2)	19 (38.8)	8 (16.3)	1 (2.0)
Product 2	3 (5.1)	19 (32.2)	12 (20.3)	9 (15.2)	9 (15.2)	6 (10.2)	1 (1.7)
Product 3	2 (3.3)	6 (10.0)	10 (16.7)	15 (25.0)	14 (23.3)	8 (13.3)	5 (8.3)
Product 4	3 (5.1)	13 (22.0)	20 (33.9)	6 (10.2)	12 (20.3)	5 (8.5)	0 (0)
Product 5	4 (6.8)	17 (28.8)	19 (32.2)	7 (11.9)	7 (11.9)	5 (8.5)	0 (0)
Product 6	2 (3.2)	9 (14.5)	11 (17.7)	13 (21.0)	20 (32.3)	6 (9.7)	1 (1.6)
Product 7	1 (1.7)	5 (8.5)	11 (18.6)	12 (20.3)	19 (32.2)	10 (16.9)	1 (1.7)
Product 8	0 (0)	3 (5.0)	15 (25.0)	9 (15.0)	27 (**45.0**)	6 (10.0)	0 (0)
Product 9	5 (8.5)	25 (42.4)	6 (10.2)	9 (15.2)	11 (18.6)	2 (3.4)	1 (1.7)
Product 10	4 (6.9)	16 (27.6)	16 (27.6)	6 (10.3)	11 (19.0)	5 (8.6)	0 (0)

2. Testees filled out personal data. This step took 2 min.
3. The tester projected the 10 product slides on the screen one by one, and testees filled out the questionnaire accordingly. This step took 40 min, i.e., 4 min per product.

4.6 Results

4.6.1 CODING AND DATA CONVERSION

The data collected were converted into a binary coding system, in which, every pair of adjectives was represented by a seven-digit binary string, representing the seven-point scale. Each digit signals a value level, from left to right, representing one to seven. A digit would be switched to '1' to signal that a mark was checked at that particular value level while the rest remained '0,' i.e., a value level of '3' on a Harmonious–Contrasting adjective pair would be represented as '0010000' and a value of '7' as '0000001'.

The above-described coding scheme was then used for cumulating the data gathered from 65 subjects on 27 adjective pairs for the 10 products. Table 2 shows part of the results for the adjective pair 'Harmonious–Contrasting' in Form Components. The number in each cell of the table represents the counts of '1's, while the value in parentheses shows the percentage out of that row. As there were some missing check marks, the total count for each product is less than or equal to 65.

4.6.2 ANALYSES

For data conversion, the maximum relative percentage of counted value among all rows ('45.0%' in this case) was used as the converting denominator. After dividing by the denominators accordingly, values that are greater than or equal to 0.5 were set to 1, otherwise to 0. A part of the results is shown in Table 3. The value in the row 'Overall Style' is set to '1' if the sum for that column is greater than or equal to 5 (10 products total), otherwise to '0'. Finally, the code for each product was compared against that of 'Overall Style'. Table 4 depicts the deviations (discrepancies) between the 'Overall Style' and 10 products with respect to the adjective pair 'Harmonious–Contrasting'.

The results are compiled in Table 5, in which the characteristics of the Bauhaus style are highlighted with the characters in bold. From Table 5, it can be detected that:

- For Form Components, slightly Harmonious with slightly Contrasting, Geometric, and Pure are found to be Bauhaus stylistic characteristics.
- For Joining Relationships, the characteristics include slightly Fragmentary, Self evident, and Static.
- For Detail Treatments: Uniform, slightly Rounded, Functional, and slightly Subtle with slightly Bold.
- For Materials: slightly Harmonious, slightly Multiple, Hard, Smooth, and Glossy.
- For Colors: Harmonious, Single with slightly Multiple, Bright, Cool, and slightly Soft.
- For Textures: Harmonious, Single, Subtle, Regular, and Tactile (3D) with Visual (2D).

Table 3. Coding after conversion on 'Harmonious–contrasting'.

	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Product 1	0	0	1	0	1	0	0
Product 2	0	1	0	0	0	0	0
Product 3	0	0	0	1	1	0	0
Product 4	0	0	1	0	0	0	0
Product 5	0	1	1	0	0	0	0
Product 6	0	0	0	0	1	0	0
Product 7	0	0	0	0	1	1	0
Product 8	0	0	1	0	1	0	0
Product 9	0	1	0	0	0	0	0
Product 10	0	1	1	0	0	0	0
Sum	0	4	5	1	5	1	0
Overall Style	0	0	**1**	0	**1**	0	0

4.6.3 DISCUSSIONS

As depicted in Table 4, the most deviations on adjective pair 'Harmonious – Contrasting' appeared on products 2 and 9 ('3' in this case) among all samples, which could then be set as the cognitive thresholds on that particular adjective pair.

The overall thresholds on all adjective pairs for Bauhaus style are summarized in Table 6, in which

Table 4. The deviation between the overall style and the 10 products on 'Harmonious–contrasting'.

	Product 1	Product 2	Product 3	Product 4	Product 5	Product 6	Product 7	Product 8	Product 9	Product 10
Deviations	0	3	2	1	2	1	2	0	3	2

Table 5. The characteristics of Bauhaus styles.

		Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Form components	Harmonious–contrasting	0	0	**1**	0	**1**	0	0
	Geometric–biomorphic	0	**1**	**1**	0	0	0	0
	Pure–impure	0	**1**	**1**	0	**1**	0	0
	Simple–complex	0	0	0	0	0	0	0
	Balanced–unstable	0	0	0	0	0	0	0
Joining relationships	Monolithic–fragmentary	0	0	0	0	**1**	0	0
	Self evident–hidden	0	**1**	**1**	0	0	0	0
	Static–dynamic	0	**1**	**1**	0	0	0	0
Detail treatments	Uniform–multiform	0	**1**	**1**	0	0	0	0
	Angular–rounded	0	0	0	**1**	**1**	0	0
	Functional–decorative	0	**1**	**1**	**1**	0	0	0
	Subtle–bold	0	0	**1**	**1**	**1**	0	0
Materials	Harmonious–contrasting	0	0	**1**	0	0	0	0
	Single–multiple	0	0	0	0	**1**	0	0
	Hard–soft	0	**1**	0	0	0	0	0
	Smooth–rugged	0	**1**	0	0	0	0	0
	Mat–glossy	0	0	0	0	0	**1**	0
Colors	Harmonious–contrasting	0	**1**	**1**	0	0	0	0
	Single–multiple	0	**1**	**1**	0	**1**	0	0
	Bright–dark	0	**1**	**1**	0	0	0	0
	Cool–warm	0	0	0	0	**1**	**1**	0
	Soft–hard	0	0	**1**	0	0	0	0
Textures	Harmonious–contrasting	0	**1**	**1**	**1**	0	0	0
	Single–multiple	0	**1**	**1**	0	0	0	0
	Subtle–bold	0	**1**	**1**	**1**	0	0	0
	Regular–irregular	0	**1**	**1**	0	0	0	0
	Tactile (3D)–visual (2D)	0	**1**	**1**	0	**1**	**1**	0

Table 6. The cognitive thresholds of Bauhaus style.

		Thresholds		
		Maximum deviation	Total	Average
Form components	Harmonious–contrasting	3	11	2.2
	Geometric–biomorphic	2		
	Pure–impure	2		
	Simple–complex	2		
	Balanced–unstable	2		
Joining relationships	Monolithic–fragmentary	3	7	2.3
	Self evident–hidden	1		
	Static–dynamic	3		
Detail treatments	Uniform–multiform	3	14	3.5
	Angular–rounded	4		
	Functional–decorative	4		
	Subtle–bold	3		
Materials	Harmonious–contrasting	2	14	2.8
	Single–multiple	3		
	Hard–soft	3		
	Smooth–rugged	3		
	Mat–glossy	3		
Colors	Harmonious–contrasting	3	16	3.2
	Single–multiple	2		
	Bright–dark	4		
	Cool–warm	4		
	Soft–hard	3		
Textures	Harmonious–contrasting	3	13	2.6
	Single–multiple	3		
	Subtle–bold	3		
	Regular–irregular	2		
	Tactile (3D)–visual (2D)	2		
Total		75	75	16.6

the value represents the maximum deviation among the 10 samples on that adjective pair.

From Table 6, it can be derived that, in general, Bauhaus style has a tighter cognitive range in the Form Components (2.2) and looser cognitive range in Detail Treatments (3.5). More specifically, 'Self Evident–Hidden' of Joining Relationships was the tightest and the loosest include 'Angular–Rounded' and 'Functional–Decorative' of Detail Treatments and 'Bright–Dark' and Cool–Warm' of Colors. These are understandable because 10 samples were chosen from various types of products with various functions, different materials, and different colors. As a result, some (parts) looked angular while some looked rounded; some looked functional yet some (parts) looked decorative; some were bright but some were dark; and some were cool (e.g., metal) whereas some were warm (e.g., wood).

5. Experiment II

5.1 Purpose

To, verify the constituent elements of cognitive thresholds for different styles.

5.2 Samples Used

Three products (slides) in different styles, viz. Product A: Memphis, Product B: Hi-Tech and Product C: Braun, were chosen as experimental samples (Figure 4).

5.3 Subjects Selected

Same subjects were selected as Experiment I for consistency.

5.4 Instruments Used

A slide projector, three slides, and a pre-designed questionnaire were used. Photos echoing each slide were also put on the top of the questionnaire, and a seven-point scale was used in the questionnaire.

5.5 Procedure

The experiment was carried out in groups in a 22 min session, and the procedure was divided into three consecutive steps as follows:

1. The tester explained to the testees the purpose of the experiment, technical terms as well as the

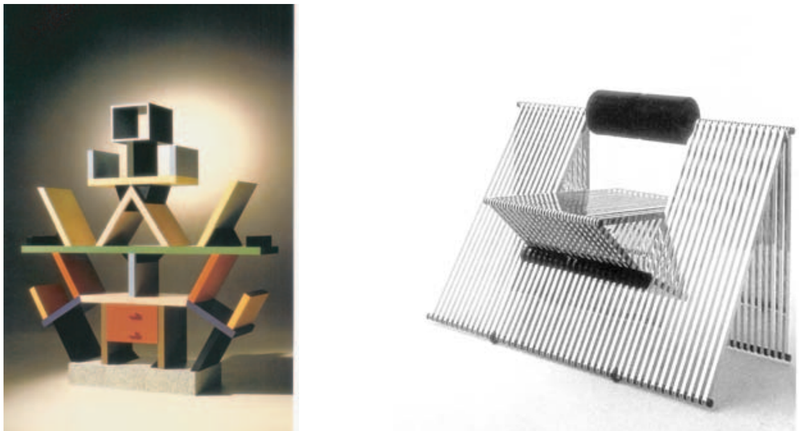

Figure 4. Two of the product images used in experiment II (left to right Memphis and Hi-Tech).

Table 7. The characteristics of product A.

		Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Form components	Harmonious–contrasting	0	0	0	1	1	1	0
	Geometric–biomorphic	1	1	0	0	0	0	0
	Pure–impure	1	1	1	0	1	1	0
	Simple–complex	0	0	0	0	1	1	0
	Balanced–unstable	1	1	1	0	1	0	0
Joining relationships	Monolithic–fragmentary	0	0	0	0	1	1	1
	Self evident–hidden	0	1	0	0	0	0	0
	Static–dynamic	0	1	1	0	1	0	0
Detail treatments	Uniform–multiform	0	1	1	0	0	0	0
	Angular–rounded	0	1	1	0	0	0	0
	Functional–decorative	0	0	0	0	1	1	0
	Subtle–bold	0	0	0	1	1	0	0
Materials	Harmonious–contrasting	0	1	1	0	0	0	0
	Single–multiple	1	1	0	0	0	0	0
	Hard–soft	0	1	1	0	0	0	0
	Smooth–rugged	0	0	0	1	1	0	0
	Mat–glossy	0	1	1	1	0	0	0
Colors	Harmonious–contrasting	0	0	0	0	1	1	1
	Single–multiple	0	0	1	0	1	1	0
	Bright–dark	0	0	0	0	1	1	0
	Cool–warm	0	0	1	1	1	0	0
	Soft–hard	0	1	1	1	0	0	0
Textures	Harmonious–contrasting	0	1	1	0	0	0	0
	Single–multiple	0	1	1	0	1	0	0
	Subtle–bold	0	1	1	1	1	0	0
	Regular–irregular	0	1	1	0	0	0	0
	Tactile (3D)–visual (2D)	0	0	0	0	1	1	0

means of filling out the questionnaire. This step took 8 min.

2. Testees filled out personal data. This step took 2 min.
3. The tester projected the three product slides on the screen one by one, and testees filled out the questionnaire accordingly. This step took 12 min, i.e., 4 min per product.

5.6 Results

The data collected were converted and cumulated as described in Experiment I. The results for products A, B, and C are shown in Tables 7–9, respectively.

Comparing Table 7 of product A with Table 5 of Bauhaus style, it can be detected that there are 13, 4, 10, 12, 16, and 5 discrepancies in Form Components, Joining Relationships, Detail Treatments, Materials, Colors, and Textures, respectively. The discrepancies shown between Table 8 and Table 5 are 11, 3, 9, 17, 9, and 8 in Form Components, Joining Relationships, Detail Treatments, Materials, Colors and Textures, respectively. Also, deviations between Tables 9 and 5 are found as 3, 4, 3, 4, 3, and 3 in Form Components, Joining Relationships,

Table 8. The characteristics of product B.

		Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Form components	Harmonious–contrasting	0	**1**	0	0	**1**	0	0
	Geometric–biomorphic	**1**	**1**	**1**	0	**1**	0	0
	Pure–impure	0	**1**	**1**	**1**	**1**	0	0
	Simple–complex	0	0	0	0	**1**	**1**	0
	Balanced–unstable	0	**1**	**1**	**1**	**1**	0	0
Joining relationships	Monolithic–fragmentary	0	**1**	0	0	**1**	0	0
	Self evident–hidden	0	**1**	**1**	0	**1**	0	0
	Static–dynamic	0	**1**	**1**	0	0	0	0
Detail treatments	Uniform–multiform	0	**1**	**1**	**1**	**1**	0	0
	Angular–rounded	0	0	**1**	**1**	0	0	0
	Functional–decorative	0	0	**1**	0	**1**	**1**	0
	Subtle–bold	0	**1**	**1**	**1**	**1**	0	0
Materials	Harmonious–contrasting	0	**1**	**1**	**1**	**1**	0	0
	Single–multiple	0	0	**1**	**1**	**1**	0	0
	Hard–soft	0	**1**	**1**	**1**	0	0	0
	Smooth–rugged	0	0	**1**	**1**	**1**	0	0
	Mat–glossy	0	0	**1**	**1**	**1**	0	0
Colors	Harmonious–contrasting	0	**1**	**1**	0	**1**	0	0
	Single–multiple	0	**1**	**1**	**1**	**1**	0	0
	Bright–dark	0	0	0	0	**1**	0	0
	Cool–warm	0	0	0	0	**1**	0	0
	Soft–hard	0	0	**1**	**1**	**1**	0	0
Textures	Harmonious–contrasting	0	0	**1**	**1**	**1**	0	0
	Single–multiple	0	0	0	0	**1**	0	0
	Subtle–bold	0	**1**	**1**	**1**	**1**	0	0
	Regular–irregular	0	**1**	**1**	0	**1**	0	0
	Tactile (3D)–visual (2D)	0	**1**	0	0	**1**	**1**	0

Table 9. The characteristics of product C.

		Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Form components	Harmonious–contrasting	0	**1**	**1**	0	0	0	0
	Geometric–biomorphic	0	**1**	**1**	0	0	0	0
	Pure–impure	0	**1**	**1**	0	**1**	0	0
	Simple–complex	0	**1**	0	0	0	0	0
	Balanced–unstable	0	**1**	0	0	0	0	0
Joining relationships	Monolithic–fragmentary	0	**1**	**1**	0	**1**	0	0
	Self evident–hidden	0	**1**	0	0	0	0	0
	Static–dynamic	0	**1**	**1**	**1**	0	0	0
Detail treatments	Uniform–multiform	0	**1**	**1**	**1**	0	0	0
	Angular–rounded	0	0	0	**1**	**1**	0	0
	Functional–decorative	0	**1**	**1**	0	0	0	0
	Subtle–bold	0	0	**1**	**1**	0	0	0
Materials	Harmonious–contrasting	0	**1**	**1**	0	0	0	0
	Single–multiple	0	**1**	0	0	**1**	0	0
	Hard–soft	0	**1**	**1**	0	0	0	0
	Smooth–rugged	0	**1**	**1**	0	0	0	0
	Mat–glossy	0	0	0	0	0	**1**	0
Colors	Harmonious–contrasting	0	**1**	**1**	0	**1**	0	0
	Single–multiple	0	**1**	**1**	0	**1**	0	0
	Bright–dark	0	**1**	**1**	0	0	0	0
	Cool–warm	0	0	0	0	**1**	**1**	0
	Soft–hard	0	0	0	0	**1**	0	0
Textures	Harmonious–contrasting	0	**1**	**1**	**1**	**1**	0	0
	Single–multiple	0	**1**	**1**	0	0	0	0
	Subtle–bold	0	**1**	**1**	**1**	**1**	0	0
	Regular–irregular	0	**1**	**1**	0	0	0	0
	Tactile (3D)–visual (2D)	0	**1**	**1**	0	**1**	0	0

Table 10. The percentage errors among products A, B, C, and Bauhaus style.

	Maximum deviation (counts) Product A	Bauhaus style thresholds Product B	Percentage errors (%) Product C		Product A/Bauhaus style thresholds	Product B/ Bauhaus style thresholds	Product C/ Bauhaus style thresholds
Form components	13	11	3	11	118.2	100.0	27.3
Joining relationships	4	3	4	7	57.1	42.9	57.1
Detail treatments	10	9	3	14	71.4	64.3	21.4
Materials	12	17	4	14	85.7	121.4	28.6
Colors	16	9	3	16	100.0	56.3	18.8
Textures	5	8	3	13	38.5	61.5	23.1
Total	60	57	20	75	80.0	76.0	26.7

Detail Treatments, Materials, Colors, and Textures, respectively.

5.7 Analyses and Discussions

The discrepancies between the cognitive thresholds of the Bauhaus style and the three products can be converted into percentage errors for better understanding the deviations among them. Table 10 summarizes the results.

In general, comparing the total percentage errors in row 'Total' for the three products, it can be found that the percentage errors (Product A/Bauhaus Style Thresholds = 80.0) > (Product B/Bauhaus Style Thresholds = 76.0) > (Product C/Bauhaus Style Thresholds = 26.7). This means that the Braun style comes first in similarity with Bauhaus style, Hi-Tech and Memphis by far are second and third, respectively. This result agrees with the general conceptions about these three styles.

Upon further examination, it appeared that between Memphis style and Bauhaus style, the percentage errors descended in such order as: Form Components (118.2) > Colors (100.0) > Materials (85.7) > Detail Treatments (71.4) > Joining Relationships (57.1) > Textures (38.5). It means most of the characteristics of the two styles are different, especially in Form Components and Colors. Memphis' extensive application of varied form elements and clamorous colors speaks for itself. Between Hi-Tech and Bauhaus styles, percentage errors depict: Materials (121.4) > Form Components (100.0) > Detail Treatments (64.3) > Textures (61.5) > Colors (56.3) > Joining Relationships (42.9). Other than the general conceptions that these two styles vary significantly, the high discrepancies in Materials may be due to the wider value range in the Harmonious – Contrasting, Hard – Soft, Smooth – Rugged and Mat – Glossy pairs scored for Hi-Tech style.

Between Braun and Bauhaus styles, percentage errors read: Joining Relationships (57.1) > Materials (28.6) > Form Components (27.3) > Textures (23.1) > Detail Treatments (21.4) > Colors (18.8). It means the two styles are quite similar except for the Joining Relationships. This may be due to both styles having different value ranges in the Monolithic–Fragmentary, Self Evident–Hidden and Static–Dynamic pairs.

6. Conclusions

The results obtained in this work reveal that: (1) the cognitive thresholds of formal style do exist; (2) the range of cognitive thresholds of a formal style depends largely on its formal consistencies; and (3) the critical elements vary with different formal styles.

Some difficulties and findings from the experiments and analyses are worthy of mention here. First, the familiarity of samples might affect the subjects' response; a well-known product can easily be categorized into that certain 'style' and distract the subjects' attention to its details. Second, the conversion of seven-level scaling into a seven-digit scoring scheme has been proven to be a better approach than a continuous value, especially when more than one centric range occurred in some adjective pairs for certain styles. For example, Memphis style has two centric ranges (1110110) in Pure–Impure for Form Components. It reveals that Memphis style applies to both pure forms (average value 2) and impure forms (average value 5.5), but not neither (average value 3.4) in a scale of 1–7. Third, real samples might be considered closer to real life than slides as some research did show that the difference will appeal when the experiment involves 'touch' sensory [7].

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