# The Effects of Form Ratio in Product Design

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**Abstract.** Product personalities are often designated for market segmentation
during product marketing, and product appearance is usually an important aspect
for determining product personality. Rational and emotional are the two oppo-
site adjectives with the most resonance during interpretation of the properties of
product forms. Among the researches on form ratio, the golden ratio is the most
historic. In this study the questionnaire survey of two group variables of
"rational and emotional properties" and "preference" among 5 kinds of ratio
states of 4 kinds of basic forms has been carried out for the purposes of
(1) figuring out the correlation among the backgrounds of respondents, the form
preference, and the rational and emotional perception, and (2) the difference in
rational and emotional perceptions of different forms. This study is also aimed at
the impacts of ratio variations of different forms on the rational and emotional
properties. Both the online questionnaire and questionnaire in paper copy have
been implemented simultaneously in this experiment for two weeks. In the end
230 online questionnaires and 220 paper copies of questionnaires have been
collected, and there are 417 valid questionnaires out of the total of 450 ques-
tionnaires. The results of these questionnaires have led to two conclusions: 1.
The one with the highest significance of impact on rational and emotional
properties and preference level is the college attended, followed by the gender.
2. The smaller aspect ratio of rectangular, the more rational it will be. The
smaller aspect ratio of the organic form, the more emotional is will be.

**Keywords:** Rational and emotional · Form · Aspect ratio

## 1 Introduction

The two opposite adjectives of rational and emotional for interpretation and description
of human personalities can also be used for interpretation and description of specific
human behaviors for achieving certain objectives, such as the behavior of product
design. Since the collection of human personality characteristics can be used for
describing certain product [1], another question is can the product properties be used to
explain how to infer the product functionality personality from the designed appearance
[2]. Among the researches on form ratio, the golden ratio is the most historic. In late
19th century the German psychologist Gustav Fechner (1801–1887) began the research
on human special reaction to golden section rectangle, and he noticed that the buildings
of different cultures actually shared the same aesthetic preference with respect to the

golden section rectangle [3]. The purpose of this study is to (1) figuring out the correlation among the backgrounds of respondents, the form preference, and the rational and emotional perception, and (2) the difference in rational and emotional perceptions of different forms.

## 2   Literature Review

### 2.1   Investigation of Form Ratio

The experiment of Gustav Fechner was repeated by Charles Lalo (1877–1953) in 1908 with a more scientific approach [4]. Based on the results of experiments in two different eras, the variation of preference levels corresponding to different rectangle aspect ratio from 1:1 to 2:5 is as shown in Fig. 1 [5]. The experiments by Fechner and Lalo are based on the main target of preference on 5:8 golden ratio. However, the result of this study indicates that the preferences on 1:1 square, 1:2 rectangle (twice the size of square) and 2:5 rectangle (the one with the greatest ratio in the experiment) have shown changes. From the perspective of ratio similarity, 1:2 is closer to golden ratio than 2:5, yet the preference level of 1:2 is obviously lower than 2:5. As indicated by the variation curve in Fig. 1, the peak of preference level is at the golden ratio 5:8, and the lowest point of the decreasing ratio to the left is at 5:6, and the lowest point of the decreasing ratio to the right is at 1:2. And the difference values of 5:6 with respect to 1:2 and 5:8 are both close to 0.4. The preference level going past the lowest point will be rising again, such that the preference levels of 1:1 and 2:5 are both showing upward trend.
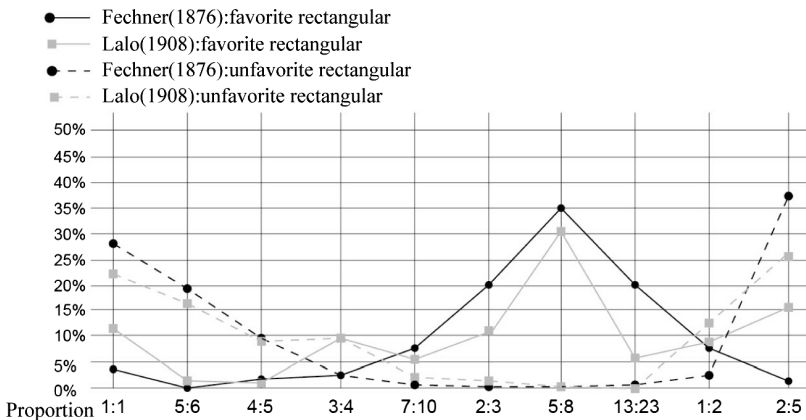


**Fig. 1.** Comparing figure of rectangle preference (on the basis of Elam (2001), this study rearrange).

Lin [6] suggested in the research on the ratio of automobile exterior dimensions that the aspect ratios of automobiles are mostly distributed at 1:2.618, which equals the golden rectangle plus another square. The rectangle based on the golden ratio of 1:1.618 is the one with the best static beauty, and the rectangle based on the ratio of

1:2.618 is the one with the best dynamic beauty. Yang [7] suggested that the ratio of cute form created by human varies in accordance with the ratio of infant, and the features created by the ratios of large head, small body, and fat and short limbs are exactly the cute factors perceived by the respondents. It indicates that the changes of ratios are influential to the properties of organic form.

## 2.2 The Rational and Emotional Properties

Kant (Immanuel Kant, 1724–1804) introduced the philosophical discourse of rationality and emotion in the book of The Critique of Pure Reason [8]. In recent years the pair of contrary adjectives "rational and emotional" has been used in researches of multiple orientations. The definitions of rational and emotional product properties can be dating back to 1980s, when Aaker and Shansby once defined product properties as: [The combination of various explicit and intrinsic features and properties of products which can be sensed by the consumers [9]. due to the market position requirement of product marketing. Japanese scholars have classified products based on whether or not the consumer is rational, thus leading to rational products and emotional products. The rational product properties are mostly product function, product quality, product price, and vendor reputation. The emotional product properties include consumer happiness, atmosphere, and fashion [10]. Hung and Chen [11] investigated the impacts of novelty of product appearance and aesthetic preferences, which included three basic dimensions of semantics — trend, complexity, and emotion. Among them, the contrary adjectives used for the emotion is "rational-emotional". This is for the definition and classification of properties for products entering the marketing stage. In this study the investigation is focused on the positioning of rational and emotional product personality at the design stage by product designer, or the future product properties which have been determined at the product planning by product planner before development design.

## 3 Research Method

In this study the questionnaire survey method has been used for the survey of the two group variables, [rational and emotional properties] and [preference], of 5 kinds of ratio states of 4 kinds of basic forms. The experiments of Fechner and Lalo are focused on the ratio of rectangle, while the experiments of Rong-Tai Lin are focused on the ratio of curve-shaped car. This study is focused on the design elements of three basic shapes — square, equilateral triangle and circle [12]. Even though the equilateral triangle is the basic element, its sharp angle feature can be visually irritant such that it is rarely used for actual products. Therefore, after eliminating the equilateral triangle and adding the curve shape and rounded square (which is frequently seen among modern industrial products such as iPhone), there are the basic states of the four forms. So there will be varying aspect ratios from 1:1, to 1:2 and 1:5, and the multiplied area of these three ratios will be the same. With the additional vertical and horizontal angles, there are a total of 5 ratios, which means there are 20 (4 × 5 = 20) different figures serve as the

sample for the first stage of experiment as shown in Fig. 2, where the numbers are shown below the figures. These 20 figures in this study are produced by the software of Corel DRAW12 in 1.5 mm black lines with white background.

Both the online questionnaire and questionnaire in paper copy have been implemented simultaneously in this experiment for two weeks. In the end 230 online questionnaires and 220 paper copies of questionnaires have been collected, and there are 417 valid questionnaires out of the total of 450 questionnaires. The basic information of the respondents are as shown below: female 221, male 196; age of 16–25: 269, age of 26–35: 58, age of 36–45: 62, age of 56–65: 4, age of 66–75: 1; education level: elementary school 2, senior high/vocational high school 22, bachelor degree 328, Master degree 53, Ph.D. 12; college attended: design and arts 230, science and engineering/electrical engineering/computer science 128, others 59; occupation: student 247, design and artwork 52, others 51, engineers 30, teachers 22, management positions 15. The questionnaire data is subject to SPSS data analysis. The first step is the reliability analysis on the two groups of combined variables of "rational and emotional properties" and "preference level" (hereinafter referred to as the two groups of combined variables), which leads to the Cronbach $\alpha = 0.746$ and $0.853$ respectively. With both number greater than 7, they indicate high reliabilities.
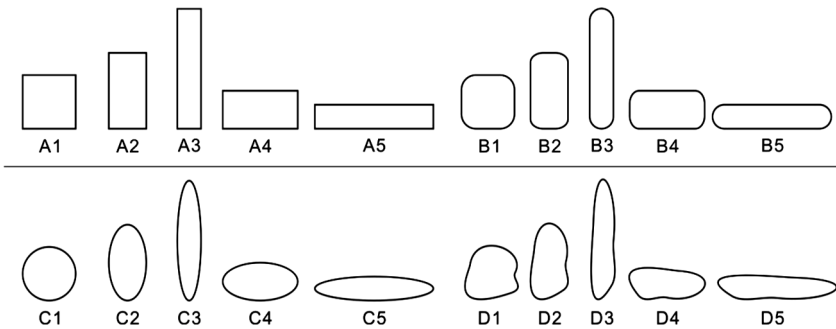


Fig. 2. Forms with no

## 4　Results and Discussions

### 4.1　The Cross Analysis Between the Backgrounds of Respondents and the Two Groups of Combined Variables

In this study the two-way multivariate analysis of variance (Two-Way MANOVA) has been used for the effect analysis of the interaction between the five basic information of respondent– gender, age, educational level, college attended, and occupation, and the "perception of rational and emotional properties" and "preference level". The one with the most significant impact on the "perception of rational and emotional properties" and "preference level" is the "college attended", followed by "gender" and "age". The occupation and educational level are not showing significant results. The next step is to figure out the difference between the reactions generated by different groups of

combined variables by Independent Sample T Test. The [college attended] is the first to be analyzed, where the original eight categories of the college attended on the questionnaire are simplified to three major categories: College of Science and Engineering (Science/Engineering/Electrical Engineering/Computer Science), College of Design and Arts (Design and Arts) and others (literature/society, commerce/management, medical/biology and others). And the Science and Engineering (N = 128) and Design and Art (N = 230) accounted for 85 % of the respondents are taken as the grouping variables. With the two groups of combined variables of [perception of rational and emotional properties] and [preference level] as the test variables, those with significance of Sig.(2-taied) < 0.05 are listed along with the mean values as shown in Table 2. The result of age is not showing any significance due to that most respondents are with the age of 16–25 (N = 269).

Table 1 indicates that in the group of [rational and emotional properties] there are C3, C4 and C5 (all in oval series) with significance in terms of the difference in perception of Science and Engineering and Design and Arts backgrounds. The respondents with science and engineering background have higher perception of rational and emotional properties of oval shape than the average value of those with

**Table 1.** Independent sample t test in different majors

|  |  | F | Sig. | Sig.(2-taied) | Mean |
|---|---|---|---|---|---|
| C3-rational and emotional | SE | 1.111 | .293 | .005 | 4.32 |
|  | DA |  |  | .004 | 3.92 |
| C4-rational and emotional | SE | .387 | .534 | .004 | 4.37 |
|  | DA |  |  | .003 | 3.93 |
| C5-rational and emotional | SE | .029 | .865 | .004 | 4.27 |
|  | DA |  |  | .004 | 3.85 |
| B1-preference | SE | .000 | .992 | .000 | 4.91 |
|  | DA |  |  | .000 | 4.24 |
| D1-preference | SE | .573 | .450 | .000 | 2.88 |
|  | DA |  |  | .000 | 3.87 |
| B2-preference | SE | .860 | .354 | .000 | 4.57 |
|  | DA |  |  | .000 | 3.91 |
| D2-preference | SE | 2.329 | .128 | .000 | 2.96 |
|  | DA |  |  | .000 | 3.66 |
| D3-preference | SE | 1.267 | .261 | .002 | 3.09 |
|  | DA |  |  | .002 | 3.77 |
| B4-preference | SE | .104 | .748 | .000 | 4.63 |
|  | DA |  |  | .000 | 3.95 |
| D4-preference | SE | .478 | .490 | .005 | 3.18 |
|  | DA |  |  | .005 | 3.73 |
| D5-preference | SE | 2.982 | .085 | .000 | 3.03 |
|  | DA |  |  | .000 | 3.83 |

Only list Sig.(2-taied)< 0.05
 SE = Science and engineering, DA = Design and Art

design and art background. In the group of [preference level] there are: B1, D1, B2, D2, D3, B4, D4 and D5, which fall into the round shapes of B series and the organic shapes of D series. Those with higher preference levels among respondents with science and engineering backgrounds than respondents with design and art backgrounds are: B1, B2 and B4, which are round shape, and horizontal and vertical 1:2 oval shapes; Those with higher preference levels among respondents with design and art backgrounds than respondents with science and engineering backgrounds are: D1, D2, D3, D4 and D5, which include all organic shapes of various aspect ratios.

## 4.2 Correlation Between Two Group Variables

The correlation between the two groups of combined variables of [rational and emotional properties] and [preference level] is as shown by the correlation matrix generated by Bivariate Correlation Analysis in Table 2. Among the $20 \times 20$ variables with $\gamma$ value of * or **, 16 variables are with significance and 4 variables are without any significance. The 4 variables inside the borders of Table 2 without any significance are: A1 rational and emotional properties × A1 preference level, A2 rational and emotional properties × A2 preference level, A4 rational and emotional properties × A4 preference level, and D4 rational and emotional properties × D4 preference level.

**Table 2.** Correlation between two group variables

| Preference<br>rational & emotional | A | B | C | D |
|---|---|---|---|---|
| 1 γ | −.036 | .186** | .196** | .140** |
| Sig.(2-tailed) | .460 | .000 | .000 | .004 |
| 2 γ | .007 | .301** | .302** | .180** |
| Sig.(2-tailed) | .879 | .000 | .000 | .000 |
| 3 γ | .146** | .305** | .296** | .251** |
| Sig.(2-tailed) | .003 | .000 | .000 | .000 |
| 4 γ | .073 | .272** | .327** | .072 |
| Sig.(2-tailed) | .139 | .000 | .000 | .144 |
| 5 γ | .115* | .263** | .272** | .242** |
| Sig.(2-tailed) | .019 | .000 | .000 | .000 |

**Sig. = 0.01(2-taied),*Sig. = 0.05(2-taied)

From these 4 matrices with no significance, it appears that the standard deviations of [rational and emotional properties] of A1and A2 are rather small (0.814 and 0.877), and the standard deviations of A4 and D4 are rather large (2.642 and 2.452). The rest of standard deviations are all between 1.241–1.934, indicating that the respondents have more concentrated rational and emotional properties with respect to A1 and A2, and for A4 and D4 they are more scattered. The mean values of [preference level] of all four groups are all around 3.5 with standard deviations between 1.6–1.7. The analysis on the 4 groups (with solid line border) with no significance is as shown below:

(1) A1 square rectangle is the one with the lowest mean value among all 20 figures at 1.31, and the lowest standard deviation at 0.814. This indicates that the perception of respondents is consistent to regard A1 as the one with the most rational properties among all 20 figures; with $\gamma = -.036$, it indicates that respondents consider this figure to be rather rational, which is negatively correlated with the preference level, and the correlation between rational level and preference level is not significant. (2) The $\gamma = 0.007$ of A2 is the lowest among all 20 figures, indicating the least correlation between the [rational and emotional properties] and [preference level]. The $\gamma = 0.073$ of A4 also falls into the category of low significance. The figures of A2 and A4 are mostly identical, with the only difference in the horizontal and vertical aspect ratios. Yet it has led to different results. In terms of the mean value, the vertical A2 is 1.51. (3) The horizontal A4 is 1.80. On average, the respondents believe that the vertical rectangle with the aspect ratio of 1:2 is more rational than the vertical one, yet the high standard deviation of A4 indicates greater difference in rational perception of the horizontal one, and the vertical one is focused on the rational perception. (4) D4 is 1:2 vertical organic shape, and $\gamma = 0.073$ indicates insignificance just like A4. The mean value of 5.46 is leaning towards emotional, and the standard deviation of 2.452 indicates a big difference in the perceptions among respondents.

## 4.3   Discussions

1. As compared to those with design and arts backgrounds, the one with science and engineering backgrounds prefer round shape, and 1:2 vertical and horizontal oval shape, and they think 1:2 vertical oval shape and 1:5 vertical and horizontal oval shape are more emotional. It appears that the emotional acceptance of those with science and engineering backgrounds is only limited to the oval shape among all four forms (rectangle, radius angle rectangle, round/oval, organic shape). The acceptance with respect to the organic shapes with more complicated curvatures. In contrary, those with design and art backgrounds prefer organic shapes, yet they don't have any significance with respect to the emotional properties of organic shapes, which means those who received trainings of higher shaping capability should be more sensitive to the forms. This has increased the requirement of assessment value of form properties, which has also led to relatively higher acceptance of high order composite curves.
2. Among the four series of figures of A, B, C, and D, A series is for rational properties, D series is for emotional properties, and C and D series are neither rational nor emotional, which are categorized as mean value based on the [rational and emotional properties] of respondents with respect to the C series. Therefore, the radius angle rectangle of the B series is equipped with both the linear and curve shaping element. In terms of the curvature of figure, round shape and oval shape are curves with regular curvatures excluding the straight line with zero curvature, and it is unlike the organic shape which is composed of curves of multiple curvatures. This is why it is in between rectangle, radius angle rectangle, and organic shapes, and determined by respondents as the mean value among all four figures. The radius

angle rectangle is not determined by respondents as the mean value because it contains straight lines, whose rational level will affect the respondents.

3. In terms of the preference level of ratio, the preference level of 1:2 is higher than 1:5 because it is more stable and thus more comfortable and safety when it comes to the human visual stimulation. And the preference level of 1:1 ratio of B1 and C1 of the B and C series are higher than other ratios, while the preference levels of B1 and C1 are the highest among all figures. It indicates that, compared to the rectangle and organic shape which are located on the two ends of rational and emotional, figures located in between rational and emotional yet leaning towards rational, such as basic figures of non-extreme radius angle rectangle and round shape with 1:1 ratio, usually have the highest acceptance as compared to the deformation and forms based on other ratios.

As for the products with either rational or emotional forms, the eventual purpose is to pursue high consumer preference level. In this study, the forms with high preference levels are those of B and C series. These forms of mean value are between the most rational and emotional forms— radius angle rectangle and round/oval shapes; so it appears that most people prefer forms with higher stability, better balance, and high visual comfort.

Mugge [2] has suggested that the product design with right angle shape generally comes with a kind of business type and serious personality. Contrarily, the product design based on radius angle shape is considered to be the more cheerful, naughty, and childish personality, which has proved the positive correlation between the curvature and business type personality. The result of experiment I of this study has revealed that the right angle rectangle is considered rational, the radius angle rectangle is with increased emotional level, and round shape and organic shape with more curves and curvature variations are with less rational level and more emotional level. The business type and serious personality shares the same personality property formed by logical reasoning and principles as the rational properties, thus indicating the rational property of form is explicit, which is best represented by the right angle rectangle. As Kant said, emotion is a kind of intuitive perception, which is also known as intuition. Intuition varies from person to person. As a result, the result of experiment I reveals that the respondent background of college attended has significantly affected the difference between the emotional property of form and the preference level of respondents. Therefore, those with design and arts backgrounds prefer organic shapes, yet they don't have higher recognition with respect to the emotional properties and organic shapes. In other words, those who are more sensitive to the forms have relatively increased the assessment requirements of form properties, and higher acceptance with respect to the high order composite curves.

## 5   Conclusions

In this study the questionnaire survey of two group variables of "rational and emotional properties" and "preference" among 5 kinds of ratio states of 4 kinds of basic forms has been carried out. The conclusions including the impacts of backgrounds of respondents and the form ratios are as shown below:

1. Among all background conditions of respondents, those with the highest significance affecting the perception of rational and emotional properties and preference levels is the college attended followed by gender, while the age and educational level have no impact at all.
2. The rectangles with smaller aspect ratios are more rational, and the organic shapes with smaller aspect ratios are more emotional.

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