# Understanding characteristics and typology of proportion in product design

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## Abstract

Proportion is one of the aesthetic elements in product design. It has been widely considered in aesthetic researches. However, no clear conclusion on proportion in product design has been suggested yet and the debate over the aesthetic pleasingness of the proportion is still ongoing. The aim of the present study is to clarify part of this ambiguity in product design through identifying characteristics and typology of product proportion through experimental design and consumer survey. For this, we constructed stimulus sets for one product category (e.g., a refrigerator) by distortion of its prototype design into various forms. Each design form was made into a product card. Then we collected consumer data by asking subjects with questionnaire to reply to questions related to product proportion. The results show that there exist various types of proportion such as stability proportion, usability proportion, functionality proportion, aesthetics proportion, conventionality proportion and harmony proportion and each product category has its own important types of proportion. Because each product category has its own important types of proportion, designers should know the important elements expressed by proportion first before they consider proportion in product design. This study gives a good answer about the matters of 'Is it possible for golden section to be applied to product design?', ‘What is proportion?’ and ‘How it should be applied?’. In addition, preferred proportion structure is different according to the consumer characteristics, successful design strategy such as niche market penetration could be performed if designers classify consumer characteristics systematically.

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## Introduction

Few would disagree with the idea that product design and product aesthetics can be powerful marketing tools. They have been characterized as key marketing elements by prominent scholars (Kotler and Rath, 1984) and practitioners. They are important strategic variables not only for consumer goods, but also for industrial products (Yamamoto and Lambert, 1994). Therefore, the importance of product design and aesthetics is gaining more systematic attention. As Nussbaum(1991) points out, “Recently, business has grown increasingly aware that design sells, U.S. companies, in particular, are rediscovering that good design translates into quality products, greater market share, and heftier profits.

Therefore, aesthetic design can take an important role in product differentiation strategies because companies will have more competitive advantages in marketplaces if they understand aesthetics as elements of differentiation. Generally, product design elements regarded as factors influencing consumer’s aesthetic responses are Simplicity/Complexity, Harmony, Balance, Unity, Dynamics, Timeliness/Style, Novelty, Gestalt, Proportion and Prototypicality and so on (Ellis 1993; Brunel 1998; Veryzer 1993b). Among these elements, proportion in product design has been widely considered in aesthetic researches. However, no clear conclusion on proportion in product design has been suggested yet and the debate over the aesthetic pleasingness of the proportion is still ongoing. One main research stream in proportion is on “Golden Section”(Benjafield, 1985). The Golden Section is a proportion ratio that finds its origins in Greek antiquity. The Golden Section proportion is obtained by dividing a line in two segments such that the ratio of the smallest segment to the largest one is the same as the ratio of the largest segment to the total line. It assumes that shapes based on this ratio are more pleasing and more natural. Advocates of the merits of the Golden Section argue that it is also a reflection of shapes (e.g. fish, shells) that can be commonly found in nature (Benjafiled, 1985; Crowley, 1991). However, other findings contradict the value of the Golden Section, and propose that it has indeed “no merits” (Boselie, 1994). Also, in a recent study, Duke (1992) applied Golden Section principles to the design of products, but did not find evidence for its superiority over other proportion ratios. We claim that the main reason of this inconsistency on Golden Section is, existing researchers just tried to answer the question of “ what is the best proportion in product design?”. And they regarded proportion as one-dimensional single relationship structure or exclusive single factor.

However, we assume that proportion is not one-dimensional or exclusive but multi-dimensional and/or defendant on some related factors. For this assumption, consider the product examples of Figure 1.

Figure 1: Two product examples transacted in the real market

Examples above in Figure 1 are actual products being transacted in the real market. It can be said that each product has its own appropriate proportion. However, it's not easy to answer the question of "why can it be said that these products have their own appropriate proportion?" Because proportion cannot be explained by mere size structure of length and width which are generally considered as proportion elements. For example, product samples in Figure 1 mean that each product has appropriate proportion. However, it can not be said that product samples in Figure 2 which have mutually reversed proportion of the refrigerator and the air conditioner have appropriate proportion. And also it's not easy to answer why these proportion reversed products are not perceived to have appropriate proportion.

Figure 2: Two proportion reversed product examples

It implies that Golden Section can not be explained by only simple relationship of width and length but be explained by multiple relationship. It means that there exist various kinds of proportion in

product design and different kinds of proportion are considered important across product category. So, each product category such as the refrigerator and the air conditioner in Figure 1 and Figure 2 includes different kinds of its own proportion. Therefore, in case that proportion is reversed in product examples such as in Figure 2, products cannot maintain appropriate proportion structure because important proportion relationship is broken. Thus, what types of proportion exist? and what are the characteristics of proportion? The study aims at answering these two questions. If these two questions can be answered, this study will clearly explain why existing proportion-related researches have given inconsistent suggestions on proportion in product design. And also, the result of this study will give useful theoretical and practical insights on how to understand and apply proportion to product design. For this, we collected proportion-related data through questionnaire from consumers and analyzed typology and characteristics of proportion, then suggested theoretical and practical implications on proportion of product design.

## Proportion as product aesthetic element

In order to define product aesthetics, it's helpful to mention a few observations about the origins of the aesthetic field. According to philosophers, aesthetics concerns the theory of art and beauty (Titus, Smith and Nolan 1986). More specifically, aesthetics is "the study of value in art" (Titus et al 1986). In the context of product evaluations, aesthetics refers to the overall beauty and attractiveness of a product. Product aesthetics relate to the artistic dimensions of products. Aesthetics elements of features such as the overall line, color, shape, pattern, texture, proportions, etc. represent artistic executional choices for product design. Overall, product aesthetics is the quality of value of these choices in the design process (Brunel 1998). Especially proportion is considered as one of the important elements for product aesthetics. The proportion is obtained when the ratio of the shortest to the longest of two lengths, for example of a rectangle or a cross, equals the ratio of the longest to the sum of the two. Various researches on the relationship between proportion and consumer's aesthetic responses have been performed for a long time. For thousands of years a widespread belief was maintained that a ratio according to the golden section deserved the status of embodying beauty beyond compare (Borissavlievitch, 1958). Ever since the pioneering work of Fechner(1876) research has therefore been focused on confirming the special attractivity of this particular ratio. The golden section ratio has obtained this special attention mainly thanks to its unchallenged mathematical beauty. However, aesthetic attractivity of the golden section was never convincingly demonstrated. Previous reviews (Zusne 1970; Berlyne 1971; Benjafield 1985; McWhinnie 1987) have pointed out that the results of empirical studies concerning the relation between the golden section and perceptual attractiveness are ambiguous and lead to opposing interpretations and conclusions. However one clear thing inferred from the past studies is that proportion is related to perceptual attractiveness. The aim of the present study is to clarify part of this ambiguity in product design.

## Experiment

This study aims at suggesting theoretical background on inconsistency of existing researches on dealing with proportion as an product aesthetic element by understanding typology and characteristics of proportion in product design and giving useful insights on how to apply proportion element to product design. For this, we constructed stimulus sets for one product category (e.g., a refrigerator) by distortion of its prototype design into various forms. Each design form was made into a product card. Then we collected consumer data by asking subjects with questionnaire to reply on the questions related to product proportion.

## Stimulus design

A refrigerator was selected for experiment stimulus from focus group interview with 9 product design-majoring graduate students. The reason that a refrigerator was selected was that design elements excepting proportion were relatively less than other products. Product cards of 21 real

refrigerators were collected from magazines and merchandise catalogs. Then one typical refrigerator was selected as a prototypical stimulus. The stimulus sets were constructed by distortion of proportion of prototypical stimulus using Adobe Photoshop 5.0. Many aspects of an object's appearance (e.g., color, perspective, shading) have the potential to affect aesthetic response. To isolate specific factors, all over visual properties were eliminated or controlled. Stimulus sets were constructed by distortion of three factors of the refrigerator (proportion of width and length, proportion of top compartment and bottom compartment, and proportion of whole size and handle size). Each factor was modified with 3 levels (high medium and low). Finally, total 27 product cards ($3 \times 3 \times 3$) were made. 3 factors for distortion and levels of distortion for designing stimulus sets are shown in Figure 3 and Table 1.

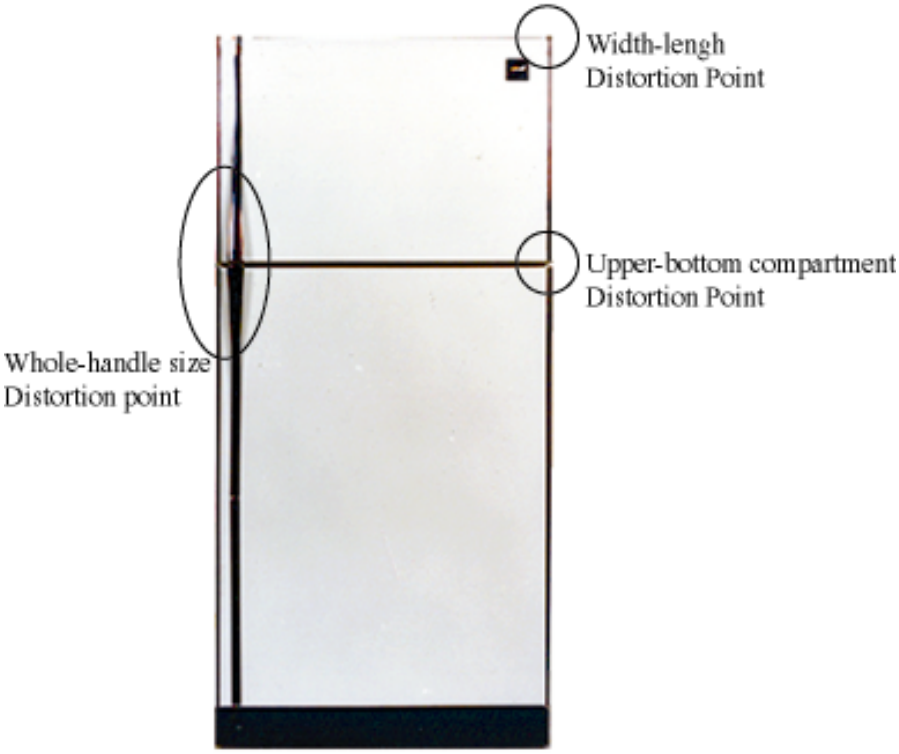


Figure 3: 3 factors for distortion

| Category | Width /length | Top compartment /bottom compartment | Whole size /handle size |
|---|---|---|---|
| Types of distortion | Extension of length | Extension of top compartment | Downsize of handle size |
| | Typical | Typical | Typical |
| | Extension of width | Extension of bottom compartment | Extension of Handle size |

Table 1: Levels of distortion

Figure 4: Shows the final stimulus sets for experiment of this study.

## Procedure

To identify the characteristics and typology of product proportion, three hundred undergraduates in an introductory design course at Chosun University participated in the experiment. Subjects were randomly assigned to a set of stimuli including five decks of products. They were asked to think of proportion only for about ten minutes on how good or bad the proportion is. Then they were given a response sheet including instructions that were read aloud to the subjects and reviewed. Then we asked subjects to write down whatever they think of proportion of stimulus sets they are looking at. So we collected the data by open-ended question method. The instructions included in the response sheet were shown in Table 2.

| |
|---|
| You are now looking five kinds of product examples. And you've thought proportion only for about ten minutes up to now. In case that you think of proportion only, which one do you think includes good or bad proportion structure. What are the reasons you think like that. Please write down whatever you think of in the response sheet. There are no right or wrong answers. Whatever you think of would be good for the responses. For example, your feeling, thinking, the reasons that you like or dislike, whatever and also, all kinds of expression such as words, phrases, short statements and long statements will be possible. There is no restriction to respond and write down whatever you think of. But please write down as many as possible. |

Table 2: Instructions in the response sheet

The purpose of this experiment is first to identify the characteristics and typology of proportion from consumer's opinion and therefore, second to understand the characteristics and typology of proportion. There was no restriction on how and what to respond, and also there was no time limit so that subjects had enough time to write down their thoughts freely. From the subjects 1,193 usable responses were obtained. The responses were then coded by two independent judges. The coding categories were developed by examining the responses by ten randomly chosen subjects (whose responses were then eliminated from further analysis). The researcher identified six categories that appeared in these responses (i.e., these categories were not based on any theory but were directly taken from subjects' responses). The number of categories was deliberately kept large since it was considered desirable to be conservative and not omit any category. The two coders then independently coded these ten responses as a practice task. The coders examined each sentence and classified it in one of the six categories that were setup earlier. This resulted in an inter-coder agreement of 89%. The coders then met and went over the responses together. The subsequent meetings with the researcher led to the coders having a better understanding of the coding procedure. Following this training phase, the coders then proceeded to code the responses of the remaining 1,179 subjects.

Among the respondents of 290 in the experiment, male is 56% and female is 44%. For the age groups, 18% are for under 10, 36% for under 20, 23% for under 30, 18% for under 40 and 5% for over 50.

## Results and discussion

The coding of the subjects' responses were first examined to find out the extent of inter-coder agreement. To assess the level of observed agreement between the two coders a kappa coefficient (Cohen's kappa), corrected for chance agreement, was calculated at an overall level for responses.

Further, kappa values were also calculated at a category level for each of the six categories to check for any major deviations in level of agreement at an individual category level compared to the overall level. The overall kappa coefficient for responses was .81. These kappa levels indicate observed agreement well above chance level (Landis and Koch 1977).

The results of categorization of responses can be seen in Table 3. The result shows that proportion in product design is not an exclusive single dimensional factor but an inter-dependent with other product characteristics and multi-dimensional factor. The coders categorized the typology of proportion into 6. They are stability proportion, usability proportion, functionality proportion, aesthetics proportion, conventionality proportion and harmony proportion. These categories were not based on any theory but were directly taken from subjects' responses. That is a kind of experimental categorization which gives useful insights to the definition of proportion which has not been effectively conceptualized. The result means that proportion in product design includes not only the ratio of width and length but also stability of product itself, ergonomic structure for user-convenience and functional form to perform the original function of product itself effectively. Also, product proportion includes conventionality which means the degree of perception of how a certain object looks typical or atypical against the existing products of same category. Changes of typical proportion led consumers to feel more new or less preferable because of difference from existing products. It means that some of consumers judge typical and familiar product proportion more aesthetic and others judge atypical and unfamiliar product proportion more appealing because of newness. In addition, product proportion is related to the harmony with the places in which the products are located and with other products which are placed together. The results, as we mentioned earlier, imply that proportion in product design is not an exclusive single dimensional factor but an inter-dependent with other product characteristics and multi-dimensional factor. That is, the proportion of product design includes not a single element but several kinds of factors such as stability, usability, functionality, aesthetics, conventionality and harmony.

| Category No. | Meanings | | Response Frequency | Response rate(%) |
|---|---|---|---|---|
| 1 | Stability proportion | Stable | 63 | 21 |
| | | Not stable | 33 | 11 |
| | | Felt uneasy | 13 | 4.3 |
| | | Balanced | 12 | 4 |
| | | Not balanced | 18 | 6 |
| 2 | Usability Proportion | Convenient to use | 18 | 6 |
| | | Not easy to use | 117 | 39 |
| | | Easy to use | 91 | 30.3 |
| | | Suitable size for the user | 15 | 5 |
| | | Inconvenient location of handle | 17 | 5.7 |
| | | Not ergonomic | 19 | 6.3 |
| | | Not suitable for user's body size | 23 | 7.7 |
| 3 | Functionality proportion | Felt functional | 125 | 41.7 |
| | | Felt not functional | 109 | 36.3 |
| | | Perform original function effectively | 20 | 6.7 |
| | | Not perform original function effectively | 19 | 6.3 |
| 4 | Aesthetics proportion | Good external appearance | 32 | 10.7 |
| | | Felt good mood | 7 | 2.3 |
| | | Aesthetic | 24 | 8 |
| | | Easy visual view | 12 | 4 |
| | | Visual inconvenience | 8 | 2.7 |
| | | Visual convenience | 11 | 3.7 |
| | | Felt narrow and close | 12 | 4 |
| | | Pleasing | 8 | 2.7 |
| | | Felt heavy | 18 | 6 |
| 5 | Conventionality proportion | Novel | 8 | 2.7 |
| | | New | 18 | 6 |
| | | Unusual | 13 | 4.3 |
| | | Innovative | 15 | 5 |
| | | Usual | 18 | 6 |
| | | Obsolete | 17 | 5.7 |
| | | Conventional | 43 | 14.3 |
| | | Familiar | 52 | 17.3 |
| | | Unfamiliar | 33 | 11 |
| 6 | Harmony proportion | Fit for the locating place | 42 | 14 |
| | | Not fit for the locating places | 36 | 12 |
| | | Good harmony with other products | 23 | 7.7 |
| | | Bad harmony with other products | 17 | 5.7 |
| Total | 6 | 38 | 1,179 | - |

Table 3: Consumers' response categories related to product proportion

The results of this study give useful insights on understanding theoretical inconsistency of existing researches which have dealt with the usefulness of golden section and regarded proportion as an aesthetic element, also have significant meanings to product design in which the proportion is

importantly considered. For the question of “Is it possible for golden section to be applied to product design?”, we suggest from the results of this study that proportion in product design plays roles as not only an aesthetic element but also stable, usable, functional, conventional and harmonic elements. The important thing here is that different types of proportion are considered according to the product categories. Only aesthetic proportion can be considered importantly in some product categories whereas more than one types of proportion are considered in other product categories. We can see some interesting proportion matters in Figure 5.

Figure 5: Various types of proportion structure

Product examples in Figure 5 have various kinds of proportion structures. It would be impossible to explain the proportion structures of above products by only golden section. The proportion structures of these products are as following in Table 4.

| Products / Ratio | a cellular phone | a TV | a refrigerator | an air-conditioner | Golden section |
|---|---|---|---|---|---|
| Width X length (cm) | 43 X 74 | 580 X 880 | 740 X 1,729 | 570 X 1,820 | 1:1.618 |
| Ratio | 1 : 1.72 | 1 : 1.52 | 1 : 2.34 | 1 : 3.19 | |

Table 4: Proportion structures of product examples

As we can see in Table 4, there exist various kinds of proportion structures in product design. Some product categories (e.g., a cellular phone, a TV etc.) have similar proportion structure to that of golden section whereas some other products (e.g., a refrigerator, an air-conditioner etc.) have quite different types of proportion structure from that of golden section.

The possible reason on the matter that proportion structures are different according to the product categories is that product categories have their own important proportion types. For example, some types of proportions like stability and harmony are not important in some product categories such as cellular phones. That’s why the proportion structure of a cellular phone is similar to that of golden

section. In some product categories such as a refrigerator, however, other types of proportions such as functionality and usability are more important than aesthetic proportion because proportion structure decides the efficiency of functional performance and ergonomic usage. In case of air-conditioner categories, if the proportion of product is structured by the ratio of golden section, the products would become more short and wide. Then they occupy more floor space and also cool air comes from middle of the air of the space. Therefore, they become inefficient for space usage and functionality. So, golden section is not suitable for those product categories.

Now we can understand why past researches trying to find out the best proportion structure in product form have suggested inconsistent results. According to the results, there exist various kinds of proportion in product form. And ideal proportion is expressed differently according to product categories because they include different types of important proportion. Therefore, it's necessary to identify important elements deciding proportion before considering proportion in product design because ideal proportion structure is influenced by those elements.

## General discussion

The results of this study suggest reasonable insights to the matter of inconsistent results of past researches on ideal proportion structure by investigating characteristics and typology of proportion through experimental stimulus design and questionnaire survey. Proportion in product design has been widely considered but no clear conclusion has been suggested yet. For this, we, from the results of our study, suggest that the proportion is multi-dimensional and includes various types. And each product category includes different types of ideal proportion structure because it includes its own important proportion. Throughout this research, 6 proportion types are identified; stability proportion, usability proportion, functionality proportion, aesthetic proportion, conventionality proportion and harmony proportion. Each product category includes its own appropriate proportion types. Therefore, golden section can be applied to some product categories whereas other types of proportion can be more appealing in other cases. Therefore, it's not reasonable to consider proportion as a single-dimensional factor such as aesthetics. Proportion in product design must be approached by multi-dimensional perspective according to characteristics of product categories. We can find out one more interesting result through the experiment that consumers' responses on same stimulus expresses wide span of preference scope from high to low. It means that preferred proportion structures, even for the same product, are different according to consumer types. Therefore, niche market penetration strategy will be possible if the preferred proportion structure is identified according to the consumer types.

In sum, the implications of the study are as follows.

First, there exist various kinds of proportion such as not only aesthetics but also stability, usability, functionality, conventionality and harmony.

Second, it's not possible to apply one common ideal proportion structure to product design and therefore designers should deliberate what types of proportion are considered important in the product they are planning to design.

Third, niche market penetration strategy will be successful if we understand the characteristics of consumer segment market because consumers' responses on even the same proportion structure are different according to consumer types.

Although the results of this study suggest useful implications to understand and apply proportion in product design, this study has several research limitations and future researches are required.

First, in the experiment of this study, we used operational stimulus sets for data collection from consumers. There is possibility that the market environment differ from these sets because they are not real in the market. In the future researches, it's necessary to use real market products to get more precise information of proportion.

Second, 6 types of proportions investigated in this study were not based on any theory but were categorized by coders' judgment. Therefore, categorization of proportion in this study is not clear and only a kind of exploratory research results to understand characteristics and typology of proportion. Next researches need to be based on clear theoretical background for categorization of proportion.

Third, in this study, only 300 subjects participated in the experiment. It's not enough to find out all kinds of proportion. Therefore, sample size should be considered for investigating more proportion types.

Finally, preferred proportion structures, even for the same product, are different according to consumer types. Therefore, it's necessary in the future researches to investigate the relationship between preference on proportion structure and consumer characteristics for niche market penetration strategy of product design.

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