

## MEASURING AESTHETIC IN DESIGN

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### 1. Introduction

Aesthetic in product design is a major factor which highly influences the consumer's decision in today's competitive market [Postrel 2001]. Considerable research has been done in order to develop a comprehensive structure and instruction to achieve a robust design methodology in applying aesthetic qualities [Khalighy et al. 2012]. However, the design process is still highly dependent on designer's perception and talent and no efficient and usable methodology has been suggested [You et al. 2006], [Yun et al. 2003]. There are two possible reasons for this issue: First, design researchers are not inherently artists. Second, design artists are not inherent researchers or they are reluctant to develop objective quantifying methods in the aesthetic evaluation [Crilly et al. 2009]. Due to the emotional and logical aspects of aesthetic, [Khalid and Helander 2006] the efforts have been unsuccessful in linking these inhomogeneous qualities [Crilly et al. 2004]. This research aims to develop an objective methodology capable of analysing product's appearance to determine the aesthetic weight/score with the ability of suggesting the possible solutions of aesthetic improvement.

### 2. The main concepts

The major concepts of aesthetic comprise of beauty and attractiveness [Khalighy et al. 2012]. According to theorists, beauty can be assumed as an internal reality while attractiveness is more external [Crilly et al. 2004]. In other words, beauty is a constant phenomenon which is not affected by external stimulus [Crilly et al. 2009]. By contrast, attractiveness is variable and derived from the concept of target which can change over time under the influence of external factors such as age, gender or culture [Khalid and Helander 2006]. Thus, unlike attractiveness beauty remains unchanged over time [Etcoff 1999].

#### 2.1 The qualities of beauty

Beauty in design consists of the design principles which have been formulised based on the human perception of pleasant features [Norman 2004]. In theory, the human brain which is based on a specific physiological pattern matches the defined correlation with the visual senses while understanding an external stimulus [Khalid and Helander 2006]. Although this pattern has not been completely discovered yet [Crilly et al. 2009], [Galanter 2010], it has gradually generated the constant results which are believed by artists and scientists as design principles [Kostellow 2002]. These principles can be summarised into four comprehensive and interactive concepts: contrast, proportion, and pureness which are described as following:

##### 2.1.1 Contrast

Contrast is generated by the concept of difference; the difference with the background or the difference between the elements in which any point that attracts the sight is a contrast. In fact contrast

is made by the design elements. Changing the thickness or size of fonts beside each other or using dark and light colours are the examples of applying contrast. The level of contrast can vary depends on the level of the variation or the number of the design elements.

### 2.1.2 Proportion

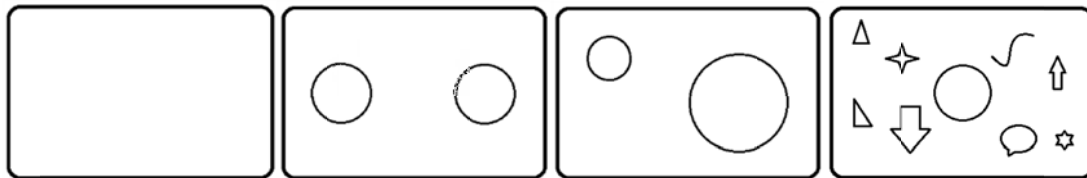
Proportion in visual art refers to the relationship between different elements which can be adjusted by changing geometry, dimensions and location of the elements. The golden ratio [Khalid and Helander 2006], [Elam 2001] is a simple example which reveals some realities about the pattern such as a demand of similarity in different aspects (only in this ratio two small and big rectangular are homologous). Proportion cannot exist without contrast. Similarity and balance in the design elements generate proportion.

### 2.1.3 Pureness

The number of elements defines pureness in which more elements means less pureness. Simplicity, being natural and clearness are the examples to indicate the pureness.

### 2.1.4 Interaction of the qualities of beauty

Contrast has reverse relationship with proportion and pureness which are inherently derived from contrast. Increasing the proportion and pureness will decrease the contrast (Figure 1).



**Figure 1. From left to right: The first figure has no element in the frame and consequently no contrast. The second figure has two elements which are same size circles. It has proportion because of applying same elements. It has pureness because there are only two elements. The contrast is higher than the first figure. The third figure has two circles with different sizes. It has proportion because both are circles. But the proportion is less than the second figure but contrast is higher. The fourth figure has many different elements. Therefore, it does not have proportion and pureness but very high contrast**

## 2.2 The qualities of attractiveness

In product design, aesthetic can be analysed in according to the aim of the product which is function [Mono 1997]. Product depends on its functionality is made from various design elements (form, detail, material, texture, colour) [Crilly et al. 2004]. The perception and expectation of the consumers of these product elements can change by variations of the functionality [Huang and Henry 2009]. However, it may vary for people with different backgrounds, cultures, ages or genders which make a subjective judgment [Khalid and Helander 2006]. In this situation, the demand of novel designs has always been a strong stimulus for designers to generate the new elements of design [Khalighy et al. 2012]. Thus, these two facts can be highlighted as the constituent factors in attractiveness: perception of function and novelty.

### 2.2.1 Novelty

Considerable research has been done in order to identify the role of novelty in aesthetic preference [Hung and Chen 2012]. However, none of these studies have been able to provide a real practical methodology to measure the novelty in aesthetic of product. Some research has indicated the U-shaped relationship between novelty and aesthetic preference that means too typical or too novel products are less preferred and the highest level of pleasantness is related to the products between these two [Coates 2003]. But there are two main issues in these investigations. First, the beauty is not affected by

attractiveness. Therefore, the less preferred product may have less amount of beauty. Second, there is no mention about the measuring which is required to directly interact with design elements. The main element as a measure of novelty can be used in order to determine the level of typicality. For instance, a car cannot be attractive as a car without the wheel. If novelty leads to removing the main element, it will be reclassified as another category of product.

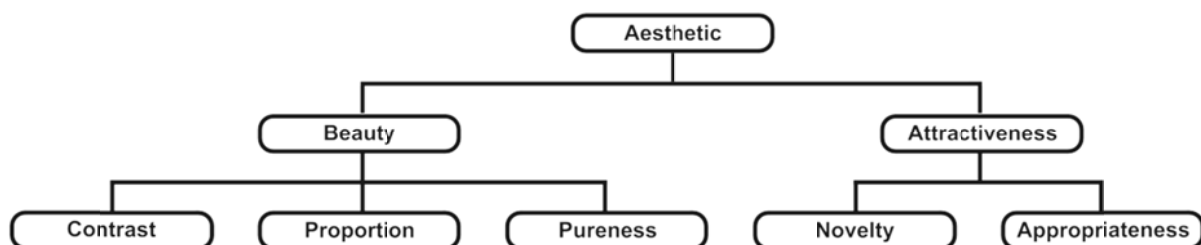
### 2.2.2 Perception of function (appropriateness)

Previous studies usually indicate the perception of function as characteristics or character of the product which normally is related to human attributes [Langmeyer and Shank 1994], [Pham 1999]. In this situation, depends on subjective attributes, people have different preference of appearance which is known by public as a different taste. However, the successful products show that some design elements are more preferred for specific function and consequently more appropriate. Therefore, what is applied in attractiveness quality is appropriateness rather than individual tastes. Although the subjective factors such as culture and social dynamics may influence the final judgment of product appearance [Bloch 1995], it is not considered as a value in measuring the aesthetic.

## 2.3 The qualities of aesthetic

In 2003 Del. Coates proposed a definition of aesthetic in product design. He has argued that aesthetic is a balance between concinnity and information [2003]. He divided concinnity in design principles and consumer features, and added novelty and contrast in information section.

There are four main issues with this definition. First, there is no mention about the function which is the main purpose of product design. Second, design principle is unclear here and all the design principles are not directly parts of the aesthetic. Third, contrast itself is a part of design principle which generates beauty whereas here is under the information section. Fourth, Novelty and contrast, and also design principles and consumer features have different nature. It does not seem to be appropriate to classify these criteria in the same category. Therefore, following classification is suggested (Figure 2).



**Figure 2. Constituent factors of aesthetic in design**

As already discussed, beauty is a certain balance between contrast, proportion, and pureness. And attractiveness is a certain balance between novelty and appropriateness.

## 2.4 Evaluation of metrics

The aesthetic qualities are applicable using the design elements [Kostellow 2002] in which each intersection defines one metric (Table 1).

There are two aspects in increasing the robustness of aesthetic qualities. First, the performance of each quality (analytical); second, how they perform while interacting with each other (compositional). For instance, if a saturated yellow and blue has higher value of aesthetic compared to impure colours, those may offer lower aesthetical pleasantness while those are utilised in one composition.

As can be seen from the Table 1, there are 30 metrics which play role in analysis of aesthetic. Some of these metrics have qualitative and others have quantitative nature. Apart from the nature of the metrics, all the qualities must be quantified in order to make an objective evaluation.

**Table 1. Analytical and compositional evaluation of aesthetic qualities (M stands for metric)**

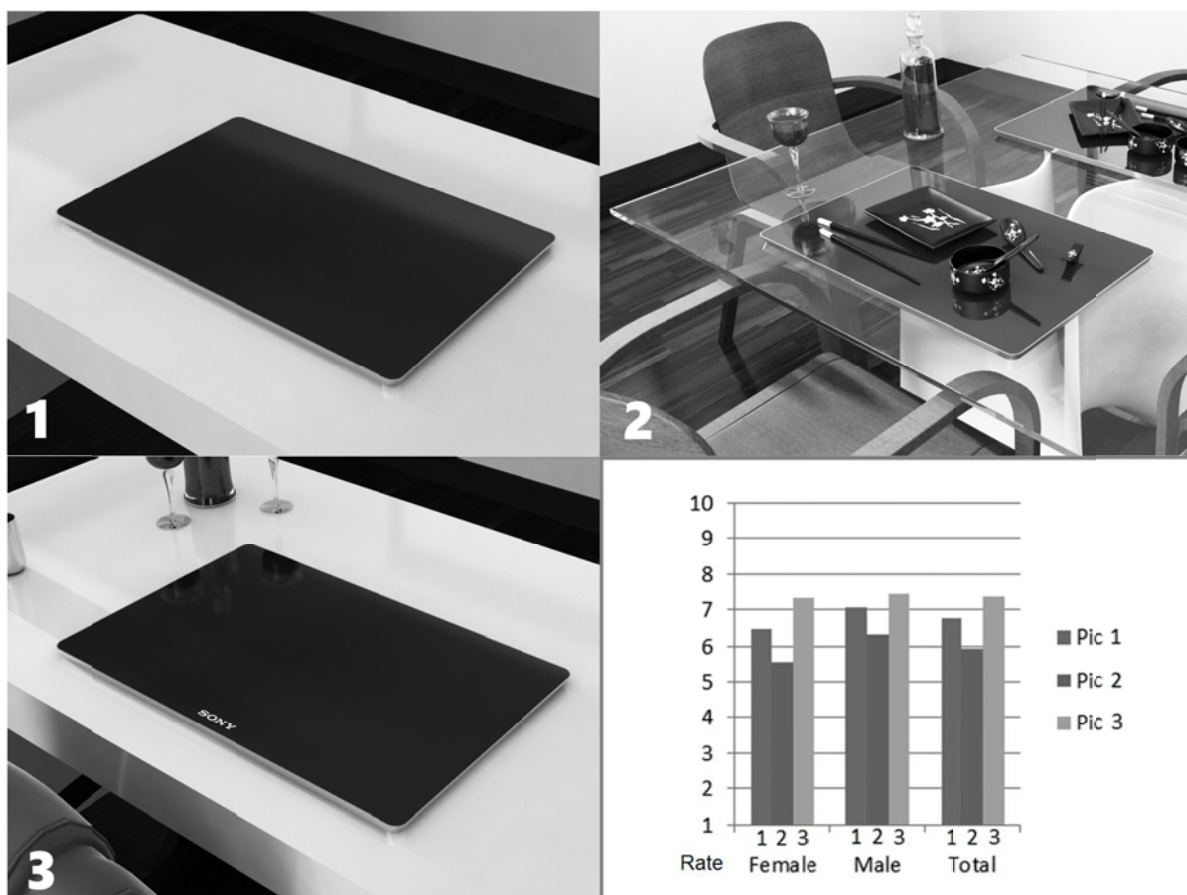
Qualities ↓ Elements →	Form	Detail	Material	Texture	Colour	Gestalt (Composition)
Contrast	M01	M02	M03	M04	M05	M26
Proportion	M06	M07	M08	M09	M10	M27
Pureness	M11	M12	M13	M14	M15	M28
Novelty	M16	M17	M18	M19	M20	M29
Appropriateness	M21	M22	M23	M24	M25	M30

### 3. Examining the main concepts

In order to test the main concepts two independent experiments were conducted. In the first experiment, the interaction of beauty and attractiveness with each other was examined. In the second test, reaction of people to the different applications of aesthetic qualities was assessed.

#### 3.1 Examining the interaction of beauty and attractiveness

In order to identify the difference in interpretation of beauty and attractiveness, the pictures of various types of product were selected. As discussed, attractiveness is meaningless in the absence of function. Therefore, in modified pictures the indication of product function was removed. Consequently, there were two similar pictures with different purposes: One with the explanation of product which contains both beauty and attractiveness and the other without any mention of the function.



**Figure 3. The result shows subjects have relatively closer opinions in the presence of both qualities of aesthetic while in the absence of function the judgment is more fluctuated. Moreover it shows that they have found this design more appropriate as a computer tablet (3) rather than a tray (2)**

In addition, products with the same design elements but with different functionality (different contexts were chosen) were provided. 56 subjects were selected from design students. 10 pictures were shown via projector. First the pictures without any function and second pictures which were indicated as a known product. The answer sheet was distributed among the subjects and they were asked to tick the one number from 1 to 10 in terms of level of pleasantness. Figure 3 shows the example of the questions and the answers.

After data analysis of the answers, it was revealed that subjects have more common opinions in preference of known products. In other words, their responses were closer when they know the function clearly. Consequently, the answers for the objects without a known function have scattered among a variety of levels of pleasantness. Furthermore, it indicates the different preferences after applying the attractiveness and its qualities such as perception of function (for one product it has raised and for another it has dropped). It shows that attractiveness exists in which final aesthetic is more understandable in the presence of both of its qualities. In other words, it is easier to judge attractiveness which is more emotional while it is more difficult to analyse beauty which is more logical. Therefore, the final judgment can vary depending on how logical or emotional the user is. Moreover, the result indicates the higher preference for the objects with a higher level of proportion and pureness.

### 3.2 Examining the preference of aesthetic qualities

This experiment is based on determining the preference of different pictures which are intentionally designed based on different levels of allocation of a certain quality. For example, three simple designs of a camera suggest a different level of proportion, pureness, and contrast, and also typicality and perception of function. In addition, it was asked to rank the designs in order to investigate the other priorities of preference. The questions were designed in the way to reveal mainly the qualities of beauty. Therefore, most of these questions have a minimum relationship with the qualities of attractiveness. 51 people from different locations of the world have participated in this experiment. Figures 4 to 8 show a few examples of the questions and the responses.

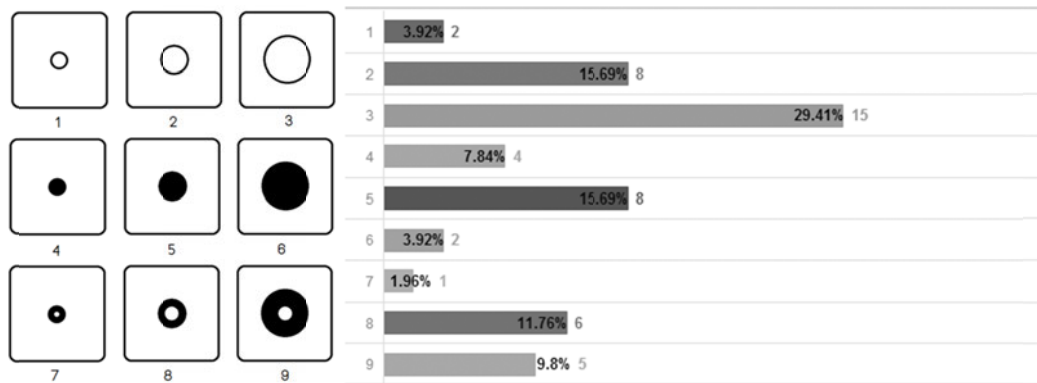


Figure 4. The figure no. 3 provides better proportion compared to figure no.2 and no.1. Due to very high level of contrast in figures no. 1, 6, and 7, they have not been taken into consideration

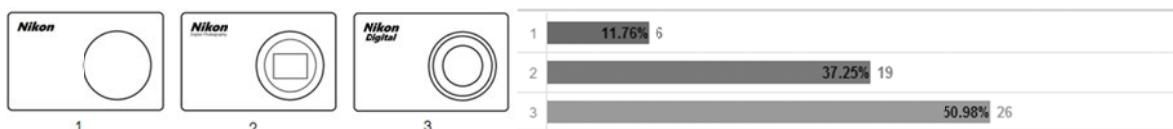
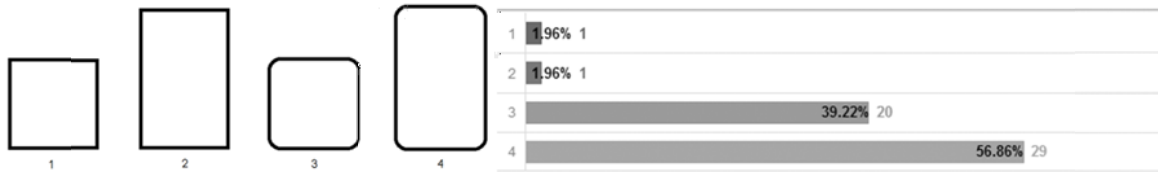


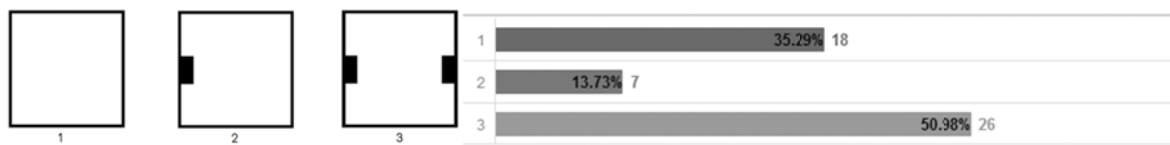
Figure 5. The figure no. 3 has the highest number of interests due to its better proportion compared to figure no. 2 which is more typical. Figure no.1 has the lowest consideration due to its low contrast



**Figure 6. Figure no.2 has the highest number of interests due to its better proportion compared to figure no.1. Figure no.2 which has the second stand seems to offer very low contrast**



**Figure 7. Round corners seem to be more pleasant compare to sharp corners. Moreover, rectangular shape is more pleasing due to higher contrast compare to square**



**Figure 8. Figure no.3 provides some amount of contrast and proportion while the contrast in figure no.2 seems to be too high**

The results of the experiment can potentially prove the theory of proportion, contrast and pureness which compose the qualities of beauty. Moreover, the nature of demand for novelty and perception of function in attractiveness category was revealed. It also indicated the preference of people for the redesigned products which have applied the suggested methodology.

#### 4. Measuring the aesthetic using eye-tracking data

Although much research has been done aiming to measure the aesthetic [Pham 1999], [Chuang et al. 2001], [Lai 2005], [Lai et al. 2006], [Cawthon and Moore 2007], [Hsiao et al. 2008], [Zain and Tey 2008], no practical measuring system in design has been provided. People based on their experiences have relative judgment of aesthetic [Jacobsen et al. 2006] and the actual value of beauty in that particular product is still unknown. In order to measure the weight of aesthetic qualities, a system will be required in which constituent factors must be quantified. Based on the definition, beauty is a balance between contrast, proportion, and pureness in which proportion and pureness are certain functions of contrast. Moreover, contrast exists at the areas which attract the concentration and it is detectable using eye-tracking device.

##### 4.1 Method of the experiment

Two groups of images were used in the experiment in which the first group contained several figures which were alphabetically labelled and the second group contained a single product in each image. The first group of images can only provide the beauty due to their non-functional nature. The second group of images provides both beauty and attractiveness because the function was clearly expressed. The eye-tracking data show the level of contrast as discussed. Because contrast has common variables with proportion and pureness, these qualities also can be measured. Therefore, the judgment of participants show which quantity is mostly preferred. The same qualities were calculated for the second group of images. This time the preference also includes the attractiveness. By using the data of the first group of images, the optimum beauty is revealed. Therefore, by adding the quantity of optimum beauty, the attractiveness can also be quantified.

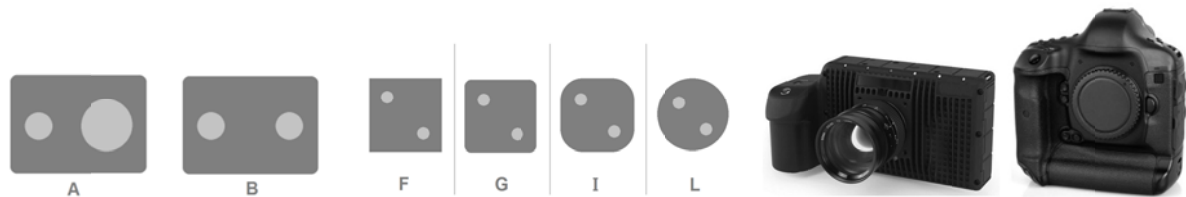
## 4.2 Conducting the experiment

The experiment was conducted with 50 subjects. They were asked to sit in front of a screen in which several images were shown and participants expressed their preferences while the eye-tracking device was placed on head of the participants (Figure 9).



**Figure 9.** The lab and the equipment were used in the experiment

In the first group of images, they verbally expressed the label of the figure which they mostly preferred. In the second group of images, they rated the images from 1 to 5 based on the judgment of appearance of the products (Figure 10). At the beginning of each task, one image was shown as a warm-up to ensure that participant is familiar with the procedure.



**Figure 10.** The trials (1, 2, 3, 4) which were used in the experiment

## 4.3 The result of the experiment

Table 2 shows the responses of the participants to the trials. The subjects were consisted of 29 male and 21 female.

**Table 2.** Number of responses and the score and the percentage of participants

Trial	1		2				3	4
Answers	A	B	F	G	I	L		
Male	9	20	2	10	9	6	71	93
	31%	68%	7%	34%	31%	20%	48%	64%
Female	12	9	0	5	16	2	58	60
	57%	42%	0%	23%	76%	9%	55%	57%
Total	21	29	2	15	25	8	129	153
	42%	58%	4%	30%	50%	16%	51%	61%

As can be seen from the results, in the first trial, figure B is preferred most which has better proportion compared to figure A. However, figure B is mostly preferred by males and figure A by females. In trial no.2, figure I has the highest number of interests followed by figure G in which figure G is preferred by males and figure I by females. Figure F and L which are complete square and circle have the lowest number of interests in which they provide very high and very low contrast respectively. It can potentially show those females are more interested in dynamic shapes whereas males prefer more

static compositions. Trial no.4 which has better proportion has achieved slightly higher score compared to trial no.3 with more novel design which shows the effect of attractiveness in the final judgment.

#### 4.4 Analysis of the data

Figure 11 to 14 show the scattered plot of eye fixations for all 50 subjects in each trial and the areas which are more concentrated by dividing into various clusters. By calculating the duration of all the fixations it was revealed that each image has been watched for about 4 seconds.

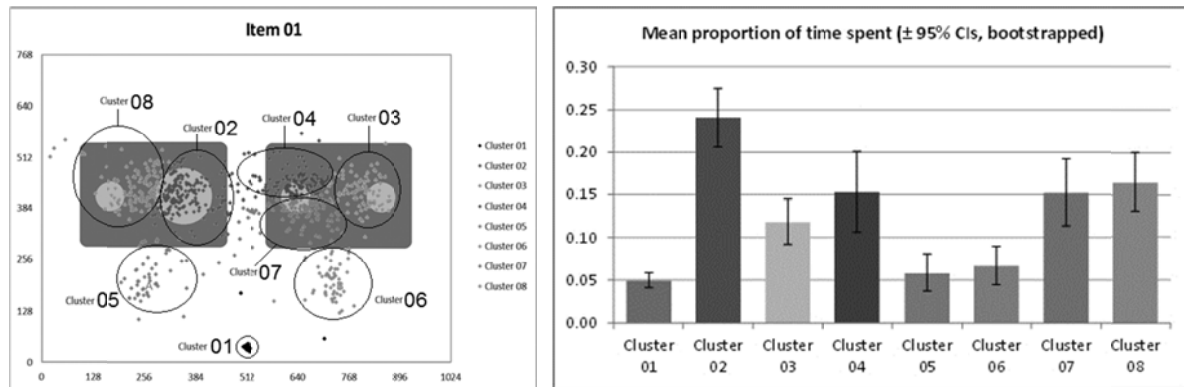


Figure 11. Scattered plot of the fixations in trial 1

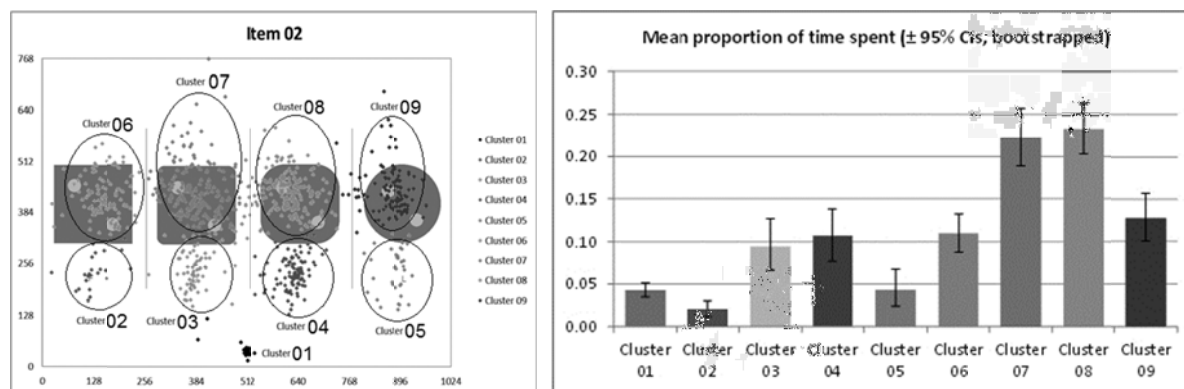


Figure 12. Scattered plot of the fixations in trial 2

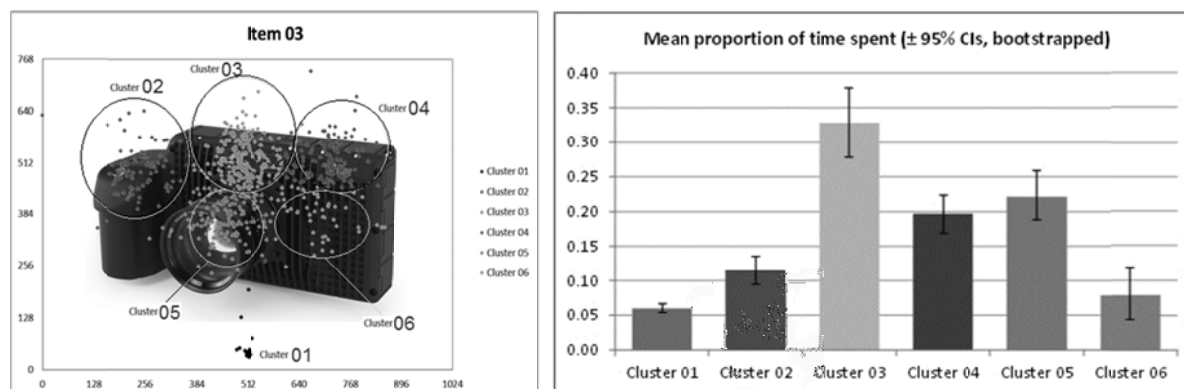
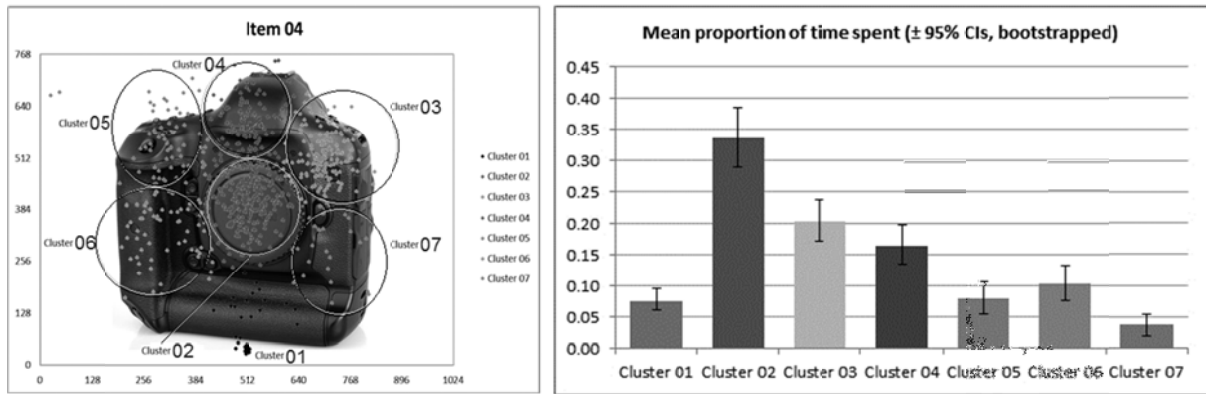


Figure 13. Scattered plot of the fixations in trial 3





**Figure 14. Scattered plot of the fixations in trial 4**

As can be seen from the figures, majority of participants have selected the figure which they have looked at for a longer time.

Based on the definition of contrast, if T= Total time, A= Average time of fixations, and D= Duration of each fixation, then contrast index (C) is measurable using the equation below:

$$C = \left( \sum_{i=1}^n |A - D|_i \right) \div T \quad (1)$$

Based on the definition of pureness, if N= Number of fixations, pureness index (Pu) is calculable applying the equation below:

$$Pu = 1 \div N \quad (2)$$

Based on the relationship between proportion, contrast and pureness, proportion index (Pr) can be measured by the equation below (it is multiplied by 0.01 to keep the number between 1 and 0):

$$Pr = (N \div C) \times 0.01 \quad (3)$$

Table 3 shows the index of contrast, pureness, and proportion for each figure:

**Table 3. Index of contrast, pureness, and proportion for each figure**

Trial	1		2				3	4
	A	B	F	G	I	L		
Contrast Index	0.31	0.27	0.26	0.25	0.22	0.08	0.28	0.30
Pureness Index	0.14	0.15	0.43	0.25	0.24	0.50	0.07	0.06
Proportion Index	0.22	0.25	0.08	0.15	0.18	0.22	0.49	0.57
Overall Preference	42 %	58 %	4 %	30 %	50 %	16 %	51 %	61 %

As can be seen from the Table 3, the suggested equations have been able to indicate the mathematical value of contrast, pureness, and proportion of the figures which match the visual qualities. In image 1, figure A has higher contrast compared to figure B due to its lower proportion and pureness. The contrast index of figures F to L in image 2 has decreased respectively while the pureness index is higher in figures F and L due to purer shapes. Proportion has increased from figure F to L due to higher similarity of the shapes. Camera 3 shows lower number of contrast while it has higher pureness which means camera 4 has better proportion. The percentage of preferences shows that the participants were more interested in the images with better proportion which still maintain a certain amount of contrast.

## 5. Conclusion

This paper endeavours to measure the aesthetic in design via subjective and objective experiments. The theory of beauty and attractiveness was examined using presentation and online questionnaire and it shows the effect of the qualities on the preferences and final judgments. The result of the objective test highlighted the initial thoughts of theory of aesthetic and it revealed its potential in measuring the qualities of aesthetic applying an accurate and high performance tool. Unlike previous efforts of measuring aesthetic, this approach is originated from the basis of the main visual concepts in conjunction with objective quantification methods.

Despite all the efforts, there were some limitations in this approach. First, it was a pilot test and consequently the number of trials was limited to four involving 50 subjects. More trials can potentially reveal more information in the interaction of the qualities and enhance the precision of the result. Second, the result can be made more accurate by increasing the number of participants. Third, the environment of the lab is not representative of the ordinary surroundings which people are normally exposed to while making their intuitive judgments. Therefore, for the future studies and experiments increasing number of trials and subjects in order to verify, improve, and develop the equations for measuring the qualities of beauty and attractiveness will be considered.

Moreover, the experiment which has employed the two-dimensional stimulus can be also conducted using three-dimensional trials to assess any differences in visual interpretations. There is a potential to explore this approach from a retail perspective such as consumer decision making based on online shopping experience to the physical experience of interacting with the product in a retail environment. Depending on the outcome, this tool can potentially enable designers, manufacturers and retailers to improve their market position.

In order to generate a comprehensive aesthetic model, a robust system must be developed. This system is required to be capable of quantifying product aesthetic in various conditions from different data sources. In addition, this system provides the solutions in order to improve the visual qualities manipulating the suggested metrics following consumer's preference. By standardising the quantitative values, it can be possible to analyse the qualitative features of designs at the different stages in order to achieve the optimum results.

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