

Impact of Curvature of Product Shape on Aesthetic Judgments

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Abstract: Competing products in the market are not widely different in terms of technical levels. Instead, their major difference lies in aesthetics and design, which are also the decisive factors of purchase decisions. Therefore, understanding consumers' aesthetic appreciation of industrial products is an important issue in the field of aesthetics and its application to consumption-related affairs. Former research indicated that people choose to stay away from sharp products and prefer curvilinear products. But what if the products under comparison are all curvilinear? Will people's preference for the same product vary with different curvatures? Do individual differences exist between people? Through this study, it has been discovered that people indeed have a preference for curvilinear products. However, regarding preference for a product with different curvatures, it does not follow that preference increases with the continued increase of curvature. At the peak, the rising trend will start to fall down. In addition, after the peak of preference appears, there is a significant difference in the major curvature between the participants with a design background and the ordinary participants. While the ordinary participants' preference for curvilinear products does decline, preference of the participants with a design background declines sharply. The above finding may serve as a reference for designers who may consider the application and timing of curves in designing product shapes in the future.

Keywords: curvilinear preference, aesthetics appreciation, product design

1. INSTRUCTION

Earlier research showed that products can evoke strong emotional responses (Girard & Johnson, 2009). People's feelings about products are apt to be affected by the external features, i.e., size, shape, color, and texture. In addition, relevant research on product experience indicated that among all senses, vision receives the largest amount of perceived information conveyed by the external characteristic elements of a product, and the information is the most intense (Schifferstein & Desmet, 2007). Therefore, people's feelings about a product largely come from the initial visual impression. As for the experience of product-purchasing, vision is the most important of all senses

(Fenko, Schifferstein, & Hekkert, 2010). Whether consumers want to buy is decided as soon as products are seen. In other words, nowadays to increase the chance of selling a product to customers, how to enhance its visual appeal is an important task. However, under such a physical condition as product appearance, what visual elements will affect people's feelings, arousing love or hate in them? Competing products in the market differ little from each other concerning function and production quality. Actually, their major difference lies in overall aesthetics, which also plays a decisive role in a purchase decision (Demirbilek & Sener, 2003). Therefore, in the fields of aesthetics and consumption-related affairs, it is an important issue to understand what is emphasized by people's aesthetic appreciation of industrial products (Liu, 2003).

People often give rapid evaluation to a product encountered by them. Such evaluation is usually a judgment based on the physical characteristics of the product (Bar & Neta, 2006). People's aesthetic judgments will be influenced by a lot of visual features. Through these visual features, designers lead people to perceive the emotions arising from expectations. In product design, it is common to use semantic techniques so that visual features of a product will generate some associations. Common practices include the use of texture, shape, color, and so on to evoke people's emotional responses. For example, a rounded and smoothed shape can cause warm feelings while a sharp shape can provoke alarming feelings (Demirbilek & Sener, 2003). In order to ascertain these feelings, empirical aesthetics often focuses on variables of external characteristics and investigates those well-defined and artificial stimuli systematically (Liu, 2003). In that way, the visual features affecting aesthetics in the process of design can be clearly understood. Furthermore, as for people's experience with the size and shape of an object, vision plays a more important role than touch (Miller, 1972; Rock & Victor, 1964). Therefore, researchers are concerned about what formal (concerned with outward form) features of a product will receive more visual preference. Then, the potentially advantageous features will be manipulated, and principles of formal preference will be deduced, such as symmetry (Jacobsen & Höfel, 2002; Tinio & Leder, 2009), prototypicality, oblique effect (Latto, Brain, & Kelly, 2000), complexity (Imamoglu, 2000), and perceptual fluency (Reber, Schwarz, & Winkielman, 2004). Since people's preference mostly results from the process of visual evaluation, visual features function like a clue, giving much inspiration. People are able to anticipate whether a certain aspect is dangerous or safe (Carbon, 2010). For example, the shape of an acute angle is a clue which can help us to detect danger and can also increase our attention (Berlyne, 1974), thus keeping us away from danger. This phenomenon is also found in interpersonal interaction. Specifically, when two people meet for the first time, one will observe the other's external features, such as shoulders, elbows, and knees. If acute angles are found in those parts, the person involved will be thought to be aggressive (Guthrie & Wiener, 1966), arousing the other's vigilance. Other previous studies explored facial experiences and interpreted their tendencies. According to the studies, if the basic external elements of a face amount to a V-shaped corner, it will generate a threatening feeling. On the contrary, the face with a rounded shape will produce a warm feeling (Aronoff, Woike, & Hyman, 1992).

Such a phenomenon not only exists in interpersonal interaction but also in people's reactions to a product. In everyday life, among the formal features of products, the sharp appearance or otherwise provides clues for people when they determine their preference quickly. To be exact, an object with the sharp appearance will increase people's attention, because they will instinctively feel threatened or endangered (Bar & Neta, 2007). Therefore, people prefer to stay away from sharp-shaped objects associated with danger and select rounded-shaped objects associated with safety. That is, people would prefer rounded-looking products over other products. Bar and Neta (2006) indicated that whether it is a real product or a meaningless pattern, the angle of a shape or the sharpness of a

corner will affect people's feelings about the object. People will prefer a curved-shaped object or one with round corners. Gordon (1909) mentioned in *Esthetics*, regarded as a textbook for psychological aesthetics, that curves are usually felt to be more beautiful than straight lines. Hsiao and Chen (2006) also suggested that there are four fundamental dimensions regarding people's emotional reactions to product forms. Among them, the emotion factor is concerned with the curvature of a product in relation to aesthetic preference (Hung & Chen, 2012). Products with a high emotional value tend to have a curvilinear, curved, or organic shape. Moreover, this perceptual phenomenon is applied to the interior design of automobiles. Thus, the curvilinear shape of automobiles holds a greater appeal for consumers than the linear shape. Meanwhile, curves can arouse people's positive emotional reactions more effectively (Leder & Carbon, 2005). The same applies to design of furniture in the living room (Dazkir & Read, 2012).

However, Bar and Neta (2006) indicated that this case of preference does not apply to all products but to those products used in daily life, and that the shape of the product itself has no special meaning, namely, the product with a neutral image, such as a watch or sofa. But this preference does not apply to a product like a knife, because it connotes sharpness and danger. In that case, the negative image exerts a greater influence on preference than a curvilinear shape. Leder, Tinio, and Bar (2011) performed further research into the image of a product perceived by people. Their study suggested that only the product that presents a positive or neutral image to people can increase people's preference through the increase of formal curvature. On the other hand, a product that presents a negative image to people cannot increase people's preference through the above method. The emotional attributes conveyed by the product itself will affect people's preference for curvilinear products. Besides, people's aesthetic experience will affect their judgment. Experienced people refer to those who are interested in a specific issue or have received some training in the related field. Experienced people have more knowledge of the related field to make judgment, while inexperienced people can mostly describe the outward characteristics as well as their own perceived emotions (Augustin & Leder, 2006). Inexperienced people are more susceptible to the effect of the sharp shape while experienced people are uniformly free from its influence (Silvia & Barona, 2009).

Nevertheless, most of the previous studies on the product shape explored curvilinear preference in the following way. The stimuli were divided into two types, i.e., sharp and rounded products, and the participants had to choose one from the two. But if the same product has different levels of curvature, will people's preference change accordingly? In other words, will people's preference also increase with formal curvature? Seen from the standpoint of design experience, preference can never increase continuously. But is there an optimum ratio of curvature to aesthetic beauty? According to the results of a pilot study conducted by the authors, as the formal curvature of a handheld device becomes larger, people do have a higher preference for it. Yet, it is not always true, for there is a peak for curvature and preference (Lu & Ho, 2013). When the curvature is greater than a critical value, preference tends to take a reverse turn; that is, people will start to dislike a more rounded product. But the pilot study was conducted only on handheld devices with a single size. Then, if handheld devices of different sizes are tested, will levels of preference change differently? In view of that, the primary purpose of the study is to investigate how the curvature and length-width ratio of a product affect preference.

2. METHOD

2.1. Subjects

The participants gave informed consent and received NT\$ 100 NT (approximately 3 USD) for their participation. The participants had not smoked cigarettes or drunk caffeinated beverages for two hours before the testing session. Additionally, none of them reported any injuries, diseases, or previous eye surgery. All reported normal or corrected-to-normal vision.

2.2. Participants

32 participants (16 men and 16 women) were involved in this study, with their ages ranging from 19 to 33 years ($M = 24.09$, $SD = 4.08$). 15 of the participants had a design background while 17 didn't. The participants gave written consent and received NT\$100 (approximately \$3) for their participation. The participants had not smoked cigarettes or drunk caffeinated beverages for two hours before the testing session. Additionally, none of them reported any injuries, diseases, or previous eye surgery. All of them reported normal or corrected-to-normal vision.

2.3. Apparatus and stimuli

The basic forms of the stimuli were selected from the top 50 cellphones and tablets on a website, ePrice (<http://www.eprice.com.tw/mobile/billboard/?top=50>), and their average length and width were taken as the bases. The average length and width of cellphones were 130.3 x 66.9 mm, and those of tablets were 238 x 158.2 mm. In addition, the length and width (38 x 38 mm) of watches were added. Namely, three different products with different length-width ratios were selected to draw the front views of the profile lines, with their brands or the elements possibly associated with brands removed. The angular changes of the products ranged from the right angle to the round angle (curve), divided into ten levels, i.e., 0 mm, 1.5 mm, 3.5 mm, 5.5 mm, 7.5 mm, 9.5 mm, 11.5 mm, 13.5 mm, 15.5 mm, and 17.5 mm. In other words, there were 30 stimuli employed in the experiment (10 curvatures \times 3 length-width ratios = 30), with some examples shown in Figure 1.

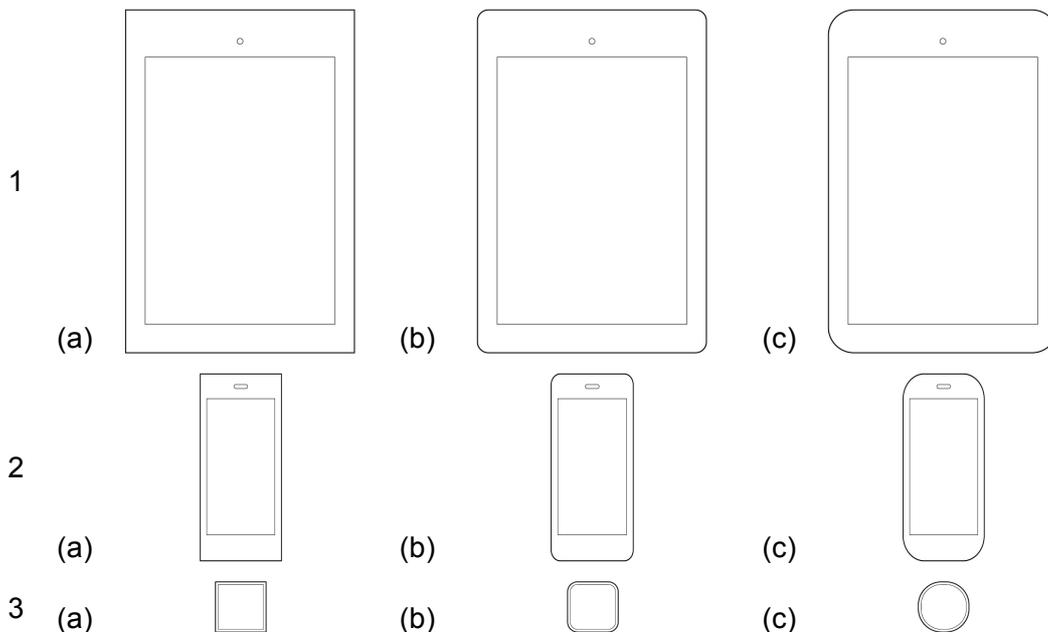


Figure 1: Different curvatures on the corners of the stimuli, scaled in proportion to their actual sizes: (a) 0 mm, (b) 7.5 mm, (c) 17.5 mm (1. Tablet, 2. Cellphone, 3. Watch)

2.4. Procedure

MacBook Pro was used in the experiment to display the experimental stimuli on a 13.3-inch screen. Its screen resolution was 1,280 x 800 pixels, and its update frequency was 60 Hz. Besides, all the experimental stimuli were controlled through the software E-prime 2 (Schneider, Eschman, & Zuccolotto, 2002). The 30 experimental stimuli were displayed in a random manner, and the pictures of the stimuli were scaled to 75% of their actual sizes in order to be easily presented on the screen

The participants were asked to give two scores as soon as possible after watching one stimulus. One of the scores was for preference, and the other was for curvature. The adopted scale was a seven-point Likert scale, in which 1 means the weakest degree while 7 means the strongest degree, with the flow chart shown in Figure 2. As the main concern of this study, the score for preference was obtained first (Carbon, 2010).

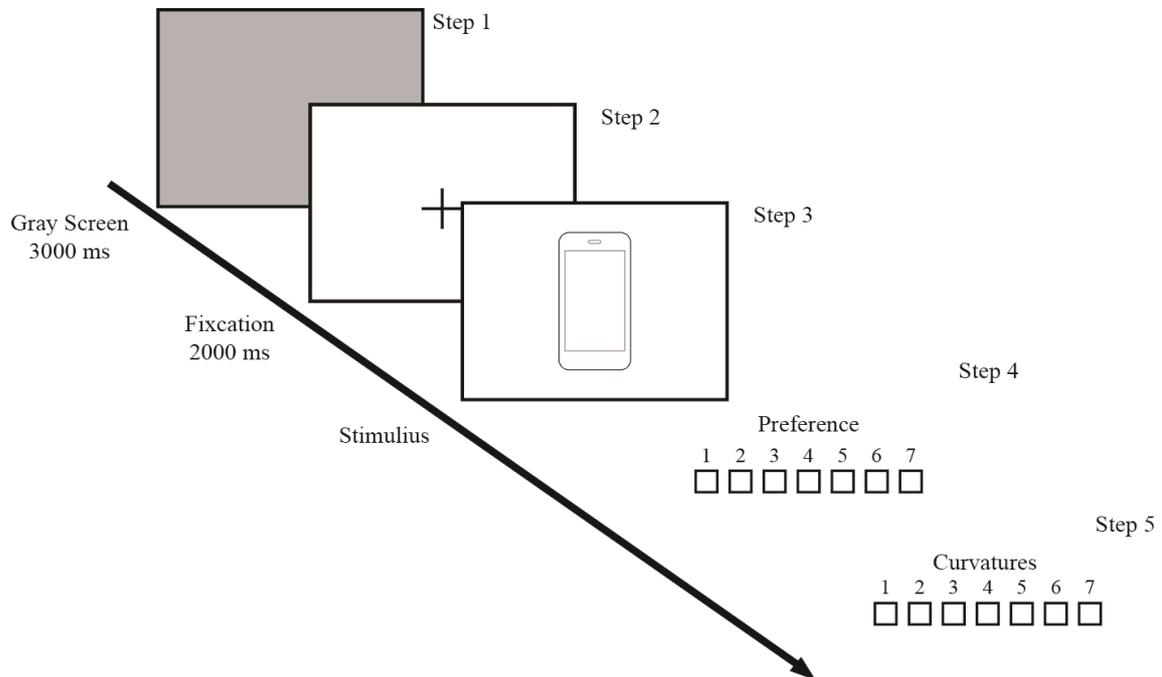


Figure 2: The flow chart of the experiment

3. RESULTS AND DISCUSSION

This study aimed to explore the relationship between people's preference and two variables, different formal curvatures and length-width ratios of products. A three-way repeated measurement analysis of variance (ANOVA) was conducted on three variables. Namely, between-group variables (subjects with or without a design background), formal curvatures and length-width ratios were analyzed in a mixed matrix. As indicated by the main effects of the participants, preferences for products with different length-width ratios showed no significant difference, with $F(2, 60) = 0.60$, $p = .55 > .05$. But there was a significant difference between different curvatures, with $F(9, 270) = 26.56$, $p < .01$. Moreover, the two variables, i.e., curvature and product type, interacted with each other, with $F(18, 540) = 5.74$, $p < .001$. In other words, products with different length-width ratios looked the same to the participants. In addition, the participants had a higher preference for the stimuli with the fifth level of curvature ($M = 4.88$) than those with the first level of curvature, or the rectangular shape ($M = 2.42$), as shown in Figure 3. From the figure, it could be discovered that the participants had a higher preference for curvilinear shapes with varying degrees than a rectangular

shape. Furthermore, as the formal curvature of a product was greater, it would receive a higher level of preference. This result is consistent with the findings of previous studies (Bar & Neta, 2006; Leder et al., 2011). In addition, the participants' scores for the ten levels of curvature of the stimuli were positively related to their scores for psychological feelings about the curvilinear shapes, with $R^2 = 0.92$. That is to say, as the physical property (curvature) of a stimulus changed, the participants' psychological feeling about curvilinear levels increased as well. But their preference for the stimulus did not increase. However, when its curvature exceeded the fifth level, a greater curvature received a lower level of preference, which was never found in any previous study.

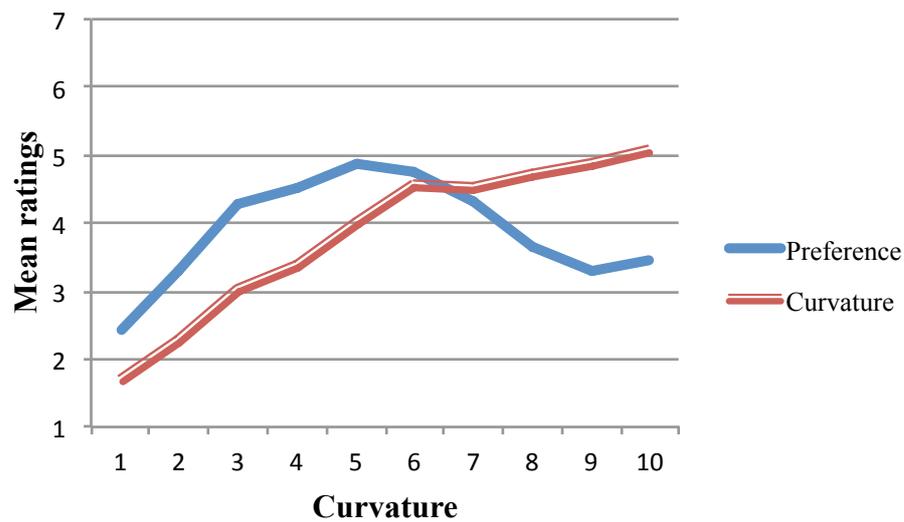


Figure 3: Mean ratings for preference and curvature in comparison

In addition, the result showed that the length-width ratio and curvature interacted with each other. Figure 4 illustrates the relationship between curvature and preference for a product with different length-width ratios. As indicated by an analysis of the simple main effect, on the third level of curvature (3.5mm), the participants' preferences for cellphones and watches were higher than that for tablets, with $F(2, 26) = 4.65, p < .05$. As for the products with a smaller size, i.e., cellphones and watches, there was no significant difference except on the eighth level of curvature (13.5mm), with $F(2, 26) = 8.28, p < .01$. Meanwhile, post-hoc analyses showed that the preferences for cellphones and tablets were higher than that for watches. The possible reason was that on the eighth level of curvature or above, the prototype of watches was already changed into a round shape. When matched with the ten levels of curvature, products with a small size (cellphones and watches) and products with a large size (tablets) underwent different trends. On the first five levels of curvature (0-7.5mm), the participants had a lower preference for tablets than for cellphones and watches, with $F(2, 26) = 3.71, p < .05$. Besides, post-hoc analyses showed that the participants' preference for cellphones was higher than that for tablets. On the sixth level of curvature (9.5mm), there was almost no difference. However, the situation was reversed on the ninth level of curvature (15.5mm). Namely, the participants' preference for tablets was higher than that for cellphones and watches, with $F(2, 26) = 5.63, p < .01$. Also, post-hoc analyses showed that the participants' preference for cellphones was higher than that for tablets.

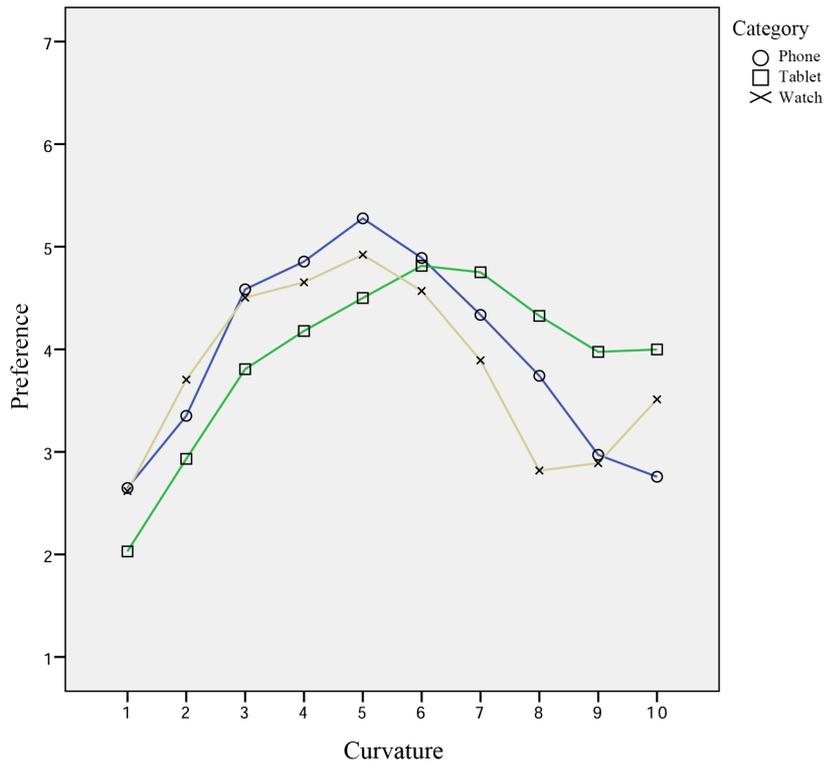


Figure 4: The participants' preference for the three types of products with different curvature

The trend in Figure 4 reveals that a large-sized product can match a larger rounded corner without causing people's dislike. Even though preference for it declines slightly, it still receives a higher preference than a small-sized product. This phenomenon may be due to the fact that there is a proper ratio of the corner radius to the side length. Namely, if the ratio of the corner radius to the side length exceeds the balance point, people will have a lower preference. As a result, the curvature of a large-sized product (a tablet) was larger than that of a small-sized product (a watch) when the highest preference appeared. In this study, for example, the participants' preference declined for the stimuli on the seventh level of curvature or above when the products had a larger size (tablets). Yet, compared with small-sized products (cellphones and watches), products with a larger size received a higher preference. Neutral products like watches were investigated by previous studies. As indicated by the findings of previous studies, more people preferred rounded-shaped watches to rectangular-shaped ones, as shown in Figure 5. Likewise, as indicated by the results of this study, the participants' preference for watches on the tenth level of curvature ($M_{\text{watch}10} = 3.53, SD = 1.69$) was higher than that for watches on the first level of curvature ($M_{\text{watch}1} = 2.59, SD = 1.16$), $t(31) = 2.65, p = .012$. But, more importantly, it is discovered that before the rectangular-shaped stimulus changes into a rounded shape, people's preference for the external shape of a product does not increase persistently, but that a peak appears. In other words, after preference reaches the peak in this process, a higher level of curvature produces a lower preference.



Figure 5: An example excerpted from previous research (Bar & Neta, 2006)

Would the participants with a design background have different reactions? With the design background taken as a between-group variable, the study made an analysis. It was discovered that there was no significant difference in product preference between the participants with a design background and those without it, with $F(1, 30) = 1.97, p = .17 > .05$. Also, the participants with different backgrounds showed no significant difference in preference for different types of products, with $F(2, 60) = 2.54, p = .09 > .05$. But the participants with different backgrounds showed a significant difference in preference for different curvatures, with $F(9, 270) = 7.43, p < .001$. In addition, there was an interaction between different backgrounds and two variables, corner curvature and product type, with $F(18, 540) = 2.36, p < .001$.

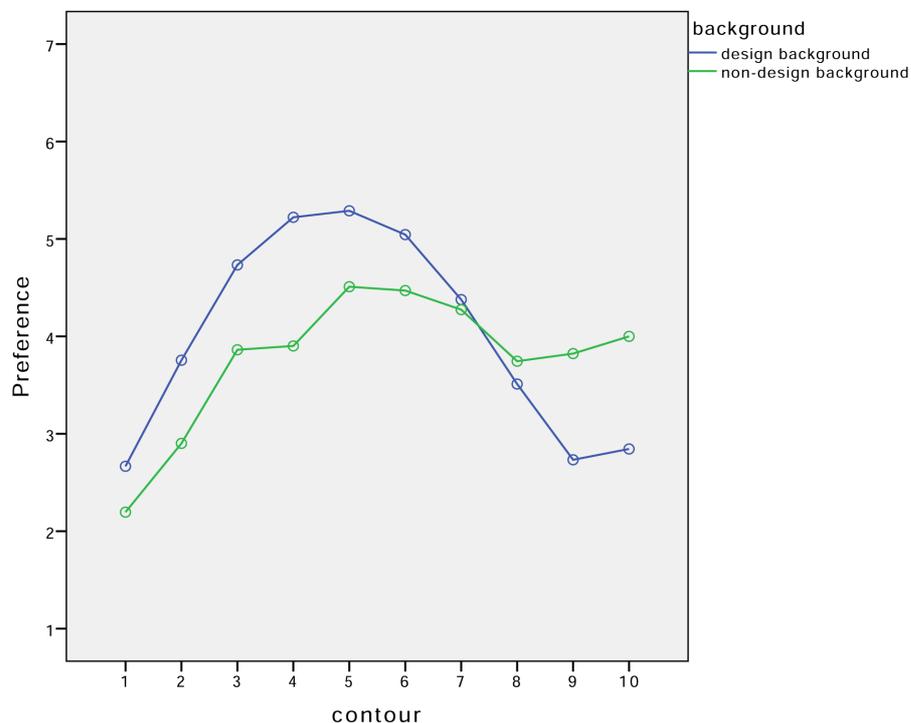


Figure 6: Preference for the stimuli displayed by the participants with or without a design background

As shown in Figure 6, there exists an interesting phenomenon; that is, regardless of whether the participant has a design background or not, the peak of preference occurs. It was proved that a

downward turn is a common phenomenon in this process. In addition, the participants with different backgrounds showed no significant difference in preference for the stimuli. However, after the stimuli were set on the seventh level of curvature, the trend of preference for curvilinear products started to differ between those with a design background and those without it. The results indicated an interaction between curvature and participants' background. As shown by the findings, regarding preference for the products on the seventh level of curvature or above, the participants with a design background are different from those without it. The former participants' preference declined abruptly while the latter participants' preference just declined slightly. Besides, compared to the former, the latter showed a higher preference for the form on the seventh level of curvature. That is to say, people with no knowledge of design are easily affected by curvilinear preference, showing a higher preference for curvilinear forms. This result may be due to the fact that experts, or people with design-related knowledge, have received training in the related fields, so they are less affected by the straight or curved shape when making preference judgments (Silvia & Barona, 2009). Experts interested in art are more sensitive to product changes, putting more emphasis on high-level design concepts (Leder & Carbon, 2005). When appreciating a piece of art, experts are more concerned about its style, while ordinary people focus on its external description (Augustin & Leder, 2006). Perhaps individual differences in focus lead to different preferences for curvature. When curvature is large, people with a design background feel the style unsuitable. Though their preference declines slightly, ordinary people still have a higher preference than those with a design background.

This study is different previous studies in terms of research settings. In addition to the respective basic forms, the three stimuli were matched with 10 different levels of curvature. As a result, it was discovered that people have a higher level of preference for curvilinear objects. Besides, it was discovered that when the basic forms of the stimuli gradually changes from a right angle to a curve, preference for them is sure to turn downward, regardless of the length-width ratio. This study suggests that preference for curvilinear forms have been well known; namely, people prefer rounded-shaped products to rectangular-shaped ones. In addition, two phenomena are noteworthy: i.e., the appearance of a peak and the match of a larger size with a greater curvature. It thus follows that there is a balance point between size and curvature. The discovery corresponds with the experience of design. To be exact, angle R in the product form cannot be increased infinitely. On the contrary, there should be a balance point between preference and the level of curvature. This discovery has never been made by previous research on curvilinear forms.

4. CONCLUSIONS

In the fiercely competitive market nowadays, consumers' feelings about a particular product and aesthetic scores for it are the main decisive factors. According to a phenomenon discovered by Bar and Neta (2006, 2007), people generally prefer curvilinear products to sharp ones. However, products on the market are not only limited to highly sharp or rounded shapes. Contrarily, there are many products with intermediate curvature. Then, what is people's preference for those products? In view of that, this study investigated product shapes with different levels of curvature. Besides, how the participants with different backgrounds liked different levels of curvature was explored, with the findings listed below.

1. People do have a higher preference for products with curvilinear shapes, which is consistent with the findings achieved by Bar and Neta (2006, 2007).

In addition to curvilinear preference concerning product shape design, there is an optimum

balance point between the side length and curvature. People have the highest preference for a product shape when its curvature reaches this balance point. Then, the preference takes a downward turn.

3. There is a difference between individuals. Specifically, most people with no design background experience the reversal of preference, but they still have a higher preference for product shapes with greater curvature than for those with rectangular shapes.

As for design practice, this study aimed to explore the effect of different curvilinear shapes on preference. Unlike previous studies, this study focused on three types of handheld devices, i.e., tablets, cellphones, and watches throughout the experiment. The results of this study can help designers get a better understanding of consumers' preference for handheld devices. By changing the shape of a handheld device and increasing the curvilinear touch of the shape, designers may enhance consumers' preference. In addition, handheld devices with a large size should be matched with a larger curvature so that products consistent with consumers' aesthetics and preference may be designed. During the experiment, all the products were scaled to 75% of their actual sizes, and their profile lines were displayed on the screen. Perhaps this might fail to completely present the consumer's feelings aroused by products in the real world. Because of that, related studies in the future can consider testing other types of products. Or 3-D effects can be used to replace the profile lines. It may be explored whether the same phenomenon still exists. Alternatively, with products excluded, only the correlation between size and curvature will be analyzed so that it may be applied to the interface design or packaging. These aspects are well worthy of being studied in the future.

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