Influence of Curvature and Expertise on Aesthetic Preferences for Mobile Device Designs

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People generally evaluate products' physical characteristics according to initial visual impressions. Previous investigations have demonstrated that sharp or curved characteristics provide clues for people to rapidly determine their preferences in daily life. In addition, previous studies have investigated the curvilinear relationship of curvature and aesthetic preferences with deviations from prototype. However, to maximize the screen size of mobile devices, deviation from the prototypical shape is not possible. Accordingly, this study utilizes mobile devices with 10 curvature levels as stimuli to explore their effects on preference when there is no departure from the prototype. Analytical results indicate that preference for the stimuli shows a peak, revealing that preference does not always rise with an increase in curvature level. Additionally, a significant difference emerges after the peak of preference, where the preference of participants with a design background declines more sharply than that of participants without a design background. Participants' judgments as to degree of product curvature indicate that people perceive a lower curvature in larger products than in smaller products. More specifically, the curvature of the product form cannot be increased infinitely; rather, a direct correlation exists between corner radius perceptions and product size. This finding may be useful for designers, who may consider the application of curves in the future design of product shapes.

Keywords – Curvature Bias, Prototypicality, Aesthetic Appreciation, Product Design, Expertise.

Relevance to Design Practice – The study demonstrates that product size affects people's perception of curvature. After a peak in preference, participants with design and non-design backgrounds showed different preferences for products. This finding may help designers to be more aware that consumers' preferences toward curvature may differ according to product size.

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Introduction

Humans prefer curved visual objects (Bar & Neta, 2006), known as the curvature bias. However, other research found a curvilinear relationship that is dependent on the prototypical shape for the category of the object (Blijlevens, Carbon, Mugge, & Schoormans, 2012), or on the zeitgeist effect (Carbon, 2010). Carbon concluded that every era has its shape. Nowadays, owing to the increase in functions of mobile devices and their lack of form freedom, such departure from the prototypical shape is not possible: the screen needs to be rectangular. Hence, the question is how designers can employ curvature to increase aesthetic pleasure, and whether they should divert their attention to other physical properties. This study investigates whether a curvilinear effect of curvature on aesthetic pleasure exists even when the fundamental prototypical shape does not change.

Curvature Bias

People frequently make rapid evaluations of the products that they encounter, usually based on physical product characteristics. Bar and Neta (2006) noted that irrespective of whether an object involves the features of a real product or a meaningless pattern, a sharp or curved contour influences people's attitudes toward that object. Bar and Neta presented two versions of stimuli, sharp and curved, to people for them to choose their preferred one.

Their results revealed that people prefer curved objects or those with round corners. One possible reason is that people's preferences mostly result from visual evaluation, and product characteristics serve as clues and provide great inspiration to users. People can utilize clues to anticipate whether a certain object is dangerous or safe (Bar & Neta, 2006). For example, the shape of an acute angle offers a clue that can help one to detect danger and can attract attention (Berlyne, 1974), thus protecting the user from danger. In everyday life, the sharp or curved appearance of a product provides clues for people to rapidly determine their preferences. Additionally, this phenomenon also exists in interpersonal interactions. Specifically, when two people first meet, one will observe the external features of the other, such as their shoulders, elbows, and knees. If these external features display acute angles, then the viewer will judge the other person to be aggressive (Guthrie & Wiener, 1966), and therefore will be

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vigilant. Other earlier studies analyzed facial expressions, and concluded that people would feel threatened if the basic external elements of a face formed a V-shaped corner (Aronoff, Woike, & Hyman, 1992). Conversely, a face with a rounded shape would generate warm feelings. Those studies indicate a fundamental bias in favor of objects with curved appearances. Moreover, Bar and Neta (2006) found that an object with a sharp appearance attracted attention because it provokes instinctive feelings of being threatened or endangered. Therefore, people stay away from sharp objects associated with danger, and prefer rounded objects, which are associated with safety. This implies that humans' preference for curved forms could be derived from natural physical reactions.

Prototypicality

In previous work, the preference for curvature is not restricted to the physiological perspective. Curvature may not itself influence preference, but instead can be adopted to manipulate the typicality of product designs (Blijlevens et al., 2012; Blijlevens, Mugge, Ye, & Schoormans, 2013; Carbon, 2010). By changing the curvature of product forms, the typicality of products was modified. People had "visual habits" at first sight, so that they often rejected new and unusual designs. According to the "Most Advanced, Yet Acceptable" (MAYA) principle, a successful product has to be as innovative as possible, yet have a design that users consider acceptable (Loewy, 1951). A change in product form that remains within the spectrum of typicality elicits a sense of novelty and preference in people. However, consumers show less preference for a product if the change in product form is greater than expected (Hekkert, Snelders, & Wieringen, 2003).

Furthermore, a previous study indicated that the correlation between aesthetic appreciation and typicality follows an inverted-U-curve pattern with five levels of change from a square-shaped product to a round-shaped one (Blijlevens et al., 2012). For example, viewers perceive novelty when major changes in form are applied to an original product that is typically square-shaped, but show a lower preference for the product when the change is greater than expected.

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Effect of Gradations in Curvature with No Departure from Prototype

To observe changes in viewers' preferences in response to minor changes in curvature that do not modify the prototype (prototypical shape) of a product, the curvature has to be divided into more finely graduated levels than in previous studies. Prior investigations classified the same type of stimulus into two versions, curved and sharp, for comparison (Bar & Neta, 2006; Leder, Tinio, & Bar, 2011; Vartanian et al., 2013; Westerman, Gardner, Sutherland, White, Jordan, Watts, & Wells, 2012), and found that a curved object is preferred in binary-choice tasks and in similarity decision tasks.

However, in product design, curvature in form is not an all-or-nothing decision: various intermediate configurations are possible. Another study categorized the stimulus into three levels of curvature, namely high, medium, and low (Leder & Carbon, 2005), while yet another investigation manipulated five levels of curvature from one prototypical shape to another (Blijlevens et al., 2012; Blijlevens et al., 2013). In summary, previous research used comparisons of two, three, or five variants to study the effect of gradations of curvature based on deviation from prototype.

However, to maximize the screen size of mobile devices, their form designs are usually tightly restricted by the shape of the screen. Therefore, significant deviation from the prototype is not possible, and new mobile devices have designs very similar to their prototype, namely a large rectangular screen with a narrow, slightly rounded screen frame. Blijlevens et al. (2012) found that aesthetic appreciation and typicality show an inverted-U-curve pattern in response to deviations from prototype. This study explores whether people's preferences for product form and variations in curvature still exhibit an inverted U-curve even in the absence of deviation from prototype.

Additionally, the relationship between level of curvature and viewers' preferences may be affected by other factors, such as other physical properties or contextual factors. Most mobile devices have a basic form, with only slight differences existing between product shapes. In the market there are many serial products that share the same design style and differ mainly in product size. Some products are perceived as aesthetically pleasing not only because of their presentation in terms of surface or structure, but also because of the product size (McManus & Weatherby, 1997). Product size is an important factor influencing people's preferences (Silvera, Josephs, & Giesler, 2002). However, the same design element (e.g., curved form) leads to different results when applied to products of different sizes. For instance, different judgments as to preference appeared when the same degree of curvature as used in tablet design was applied to smart watches. A certain proportional relationship may exist between the "size" of a tablet screen and the "curvature" feature. Therefore, designers should consider size and design features simultaneously in product design. However, no previous related research has explored the effect of preference on the proportional relationship between size and curvature. Hence, for this study we selected three products of different proportions, and adopted their average forms as the sizes of stimuli.

The differences between experts and novices were an important issue in a previous study on art appreciation. Experts who had received professional training had abundant knowledge of the specific field compared to novices, enabling them to hold perspectives different from the general public in terms of product preferences. The experts' reactions of aesthetic admiration were related to style, while the novices focused more on personal feeling (Augustin & Leder, 2006).

Silvia and Barona (2009) conducted a study on the preference reactions of experienced persons (experts) and non-experienced persons (novices) toward angularity, using non-meaningful images as stimuli in their two experiments. They investigated whether angularity influences the preferences of experts and novices. However, their conclusions on experience-influenced preferences were not consistent. The final part of the study suggested that future research might focus on criteria distinguishing the experienced and the non-experienced, as well as the various balancing and complexity factors of stimulus. Therefore, the present study divided the participants into those with and those without design backgrounds. Frequently used mobile devices were selected as the stimuli. The selected stimuli only differed in level of curvature, in order to explore whether experts and novices had the same judgements of preference for product form curvature.

The Present Research

The main purpose of this study is to investigate the effect of curvature and expertise on aesthetic preferences for mobile device designs. The forms of commonly encountered handheld devices and of watches were chosen as the stimuli for the test to avoid the issue of products triggering negative emotions (Bar & Neta, 2006; Leder et al., 2011) discussed previously. The hypotheses of the study are as follows: (a) people's preferences for product form and variations in curvature exhibit a curvilinear relationship in the form of an inverted U-curve; (b) people have varied preference reactions toward levels of curvature exhibited on different-sized product forms, and (c) a design background influences people's judgments on curvature preference.

Methods

Participants

This study involved 32 participants (16 men and 16 women) ranging in age from 19 to 33 years ($M = 24.09$, $SD = 4.08$). Fifteen participants had a design background, defined as at least two years' design experience, while 17 did not. The participants provided informed consent and received NT$100 (approximately US$3) as a token of appreciation for their participation. None reported any injuries, diseases, or previous eye surgery. All participants reported normal or corrected-to-normal vision.

Apparatus and Stimuli

The stimuli comprised products with features that can be highlighted in a front view, such as watch faces and touch screens. In other words, the main features can be presented by means of a front view. For this reason, the study was able to control variables clearly and precisely. Two types of stimuli were applied in this study: those with no deviation from prototype and those with deviations from prototype.

Firstly, the basic stimulus forms were selected from the top 50 smartphones and tablets on the ePrice website (www.eprice.com.tw) on April 23, 2013, and their average length and width were taken as the bases. The average length and width of smartphones were 130.3 × 66.9 mm, while those of tablets were 238 × 158.2 mm.

Secondly, to verify the results relating to watches in previous research (Bar & Neta, 2006), this study also selected watches (38 × 38 mm) that deviated from prototype when applying the gradations in curvature. Thus, three different products of different sizes were chosen, and front views of their profile lines were drawn with brands and associated elements removed. Figure 1 illustrates some examples of the stimuli.

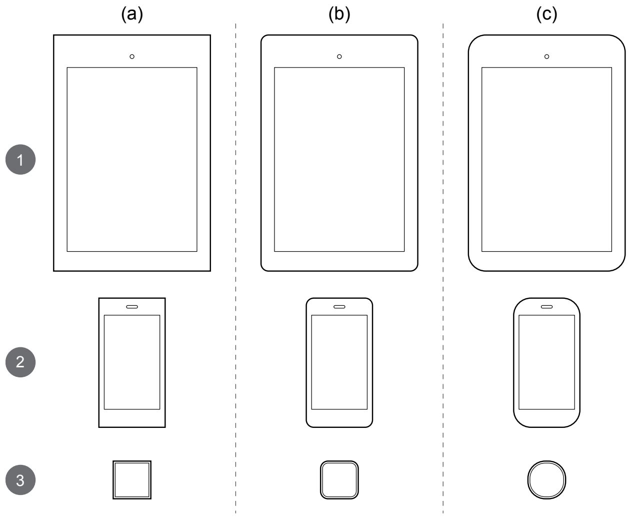

Figure 1. Different curvatures on the corners of the stimuli, scaled in proportion to their actual sizes: (a) 0 mm, (b) 7.5 mm, and (c) 17.5 mm (1: tablet, 2: smartphone, 3: watch).

Previous investigators have argued that additional detail can be found if the curvature is manipulated systematically (Leder et al., 2011; Vartanian et al., 2013). Conversely, the corner curvature design of current mobile devices is not an all-or-nothing decision, as various intermediate configurations are possible. Thus this study utilized additional gradations of curvature to understand the differences in humans' preferences. This study established 10 levels of curvature in order to elucidate the relationship between curvature and people's preference for products. The products' corner curvatures ranged from a right angle to a gentle curve, and were divided into ten levels, with radii of 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, the experiment employed 30 stimuli (10 curvatures × 3 product types = 30), as shown in the Appendix.

Procedure

In the experiment, a MacBook Pro was used to present the experimental stimuli on a 13.3″ screen with a resolution of 1,280 × 800 pixels and a refresh rate of 60 Hz. Due to the size of the screen, the stimuli could not easily be displayed at full size. Since the stimuli adopted in previous studies, including cars, sofas, and small kitchen appliances, were rarely presented at their original sizes, the stimuli in this study were scaled to 75% of their actual sizes for ease of presentation on the screen. The experimental stimuli were controlled using the software E-Prime 2 (Schneider, Eschman, & Zuccolotto, 2002). The 30 stimuli were displayed in random order. After viewing a stimulus, the participants were asked to assign two scores as soon as possible: the first score indicated preference, while the second indicated curvature. The scales adopted were 7-point Likert scales, in which 1 meant the weakest degree, while 7 was the strongest. The scales were presented at the bottom of the screen. After participants assigned the first score, the first scale was removed and the second scale was shown. Figure 2 shows a flowchart of the experiment. The score for preference was obtained first because it was the main focus of this study (Carbon, 2010).

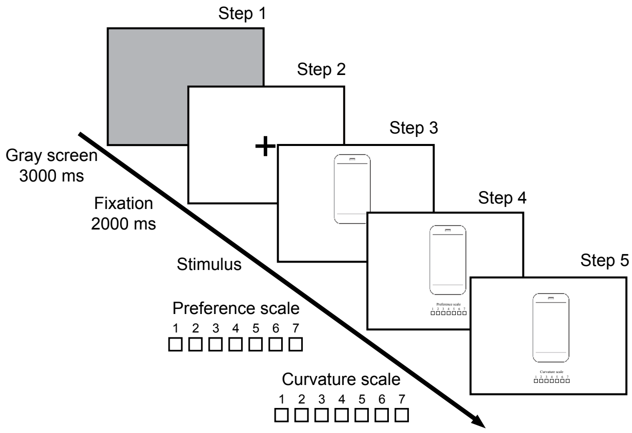

Figure 2. Flowchart of the experiment.

Results

Participants' ratings of the curved shapes were positively related to the ten levels of stimulus curvature, with $R^2 = .92$, as illustrated in Figure 3. In other words, as the radius of curvature of a stimulus increased, the level of curvature as perceived by the participants also increased. That is, they noticed that the curvatures of the stimuli had changed.

In this study, the independent variables were curvature and size as within-factors, and design background as a between-factor. All variables were transformed to the Z-transform before analysis. This study examined linear and quadratic relationships between preference and curvature. First, a regression was computed to determine whether a linear relationship existed between the participants' preferences for stimuli and curvature levels. The results, expressed as a linear relationship, were: $R^2 = .003$, $F(1, 958) = 2.49$, $p = .12$, $\beta = .051$, $p = .12$; the quadratic relationship was $R^2 = .162$, $F(2, 957) = 92.66$, $p < .001$, $\beta = -.464$, $p < .001$. That is, the result suggested an inverted-U-curve relationship between participants' preference and curvature level. Additionally, a significant correlation was observed between aesthetic preference and design expertise: $R^2 = .005$, $F(1, 958) = 5.02$, $p < .05$, $\beta = .145$, $p < .05$. A significant correlation was also observed between aesthetic preference and design expertise for the quadratic relationship $R^2 = .177$, $F(3, 956) = 68.47$, $p < .001$. The following regression model was used:

$$\text{Aesthetic Preference} = -0.268 \times (\text{Curvature Level})^2 + 0.21 \times \text{Design Expertise} - 0.213 \times \text{Design Expertise} \times (\text{Curvature Level})^2$$

Figure 4 reveals that the peak preference phenomenon still occurred regardless of whether the participants had a design background. The results also show a downward turn for both types of participants. However, preference declined more sharply in participants with a design background, falling below that of participants without a design background after the seventh level of curvature.

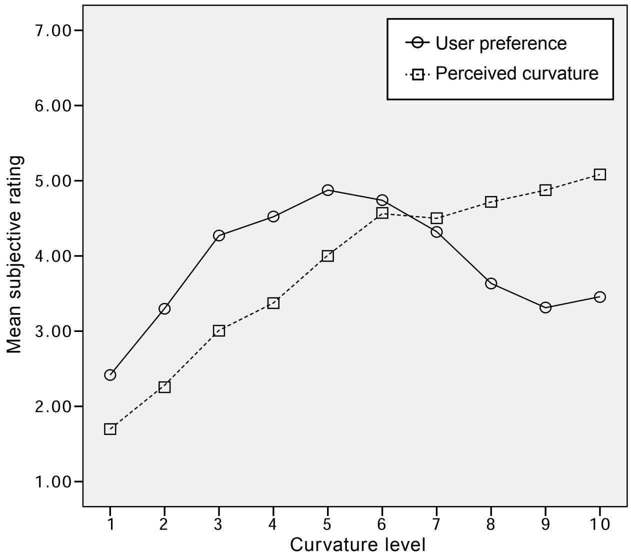

Figure 3. Comparison of mean ratings for preference and curvature.

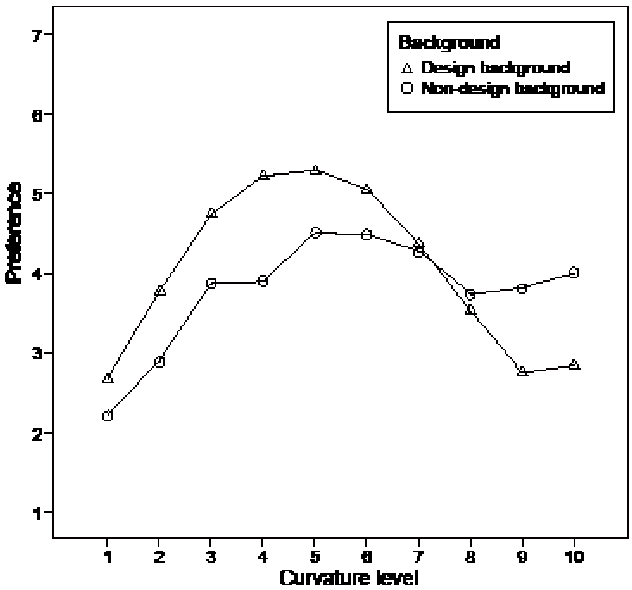

Figure 4. Preference for stimuli expressed by participants with and without a design background.

The watch was different from the other two stimuli, since changes of curvature in a watch also change its prototypicality. Therefore, the watch was excluded from the following analysis. Afterward, no difference in aesthetic preference was found between two product categories (smartphone and tablet). However, the interaction between size and curvature was significant (as shown in Table 1) when size was used as a mediator using regression. Finally, Table 2 lists the correlations among three variables, namely product size, design expertise, and curvature level.

Table 1. Size as a mediator using regression.

	β	*SE*	*t*	*p*
Intercept	.629	.077	8.129	.000
Size	-.210	.109	-1.921	.055
Curvature^2	-.595	.059	-10.133	.000
Size * Curvature^2	.194	.083	2.333	.020

Table 2. Size, expertise, and curvature regression model.

	β	*SE*	*t*	*p*
Intercept	.548	.105	5.242	.000**
Size	.051	.157	.325	.746
Curvature^2	-.480	.079	-6.051	.000**
Size * Curvature^2	.254	.112	2.266	.024*
Expertise	.173	.153	1.133	.258
Expertise * Curvature^2	-.245	.116	-2.118	.035*
Size * Expertise	-.492	.216	-2.278	.023*
Size * Expertise * Curvature^2	-.129	.164	-.787	.431

Discussion

Curvature and Preference

Figure 3 reveals a curvilinear relationship between people's preference and product curvature. As indicated by the findings of previous studies (Bar & Neta, 2006; Leder et al., 2011), people preferred rounded watches to rectangular ones. Similarly, the analytical results of this study confirm that participants had a greater preference for watches at the tenth level of curvature (as illustrated in Appendix Figure A10) than for watches at the first level of curvature (as illustrated in Appendix Figure A1). However, those studies did not address variation in the level of curvature. By means of the experimental setting (10 curvature levels), this study found that the relationships between product form curvature level and preference were quadratic. Thus, expressed levels of preference increased with increases in the level of curvature, then reversed after the peak, such that preference then decreased as level of curvature further increased.

Within the spectrum of typicality, this study specifically focused on minor changes in form. Unlike the watch, both smartphone and tablet represented changes in form without deviation from prototype. However, the results were similar to those of Blijlevens et al. (2012), that the relationship between people's preference for product form and different levels of curvature still exhibits an inverted U-curve even without deviation from prototype. One possible reason is that maximizing smartphone and tablet screen size restricts the possibility of form change in mobile device design. Therefore, the form is nearly always a large rectangular screen with a narrow, slightly rounded screen frame. Thus, people pay much attention to design details, including small variations in curvature, as an important indicator of product identity. Consequently, a minor change within the spectrum of typicality could elicit a sense of novelty in people, while a large change would exceed people's expectations, so that the aesthetic preferences produce an inverted U-curve.

Another possible reason is that people's preferences regarding curved form are influenced by zeitgeist effects (Carbon, 2010). Hsiao and Chen (2006) observed that in terms of the emotional reactions elicited by products, forms that conform to the trend of the era would receive higher preference. People would not accept forms that significantly deviate from the trend, or are excessively novel, and would give them lower preference.

Preference and Size of Product

Regression analysis indicates that no interaction occurred between product size and aesthetic preference. However, the results of pairing different product sizes with different curvature levels reveal that product size significantly influences the correlation between aesthetic preference and curvature level. Thus, if a designer applies the same curvature level to different-sized products, then the aesthetic preferences are different. Furthermore, the results for perception of product curvature imply that people perceived different curvature levels when "the same" curvature level was applied to products of different sizes. Participants perceived larger products as having lower curvature than smaller products. Accordingly, while the preference for smaller products exhibited a reverse trend, the preference for larger products did not decline sharply, since larger products had a lower perceived curvature level than smaller products. Under conditions of higher levels of curvature, the tablet acquired a preference exceeding the other products (as shown in Figure 5). In summary, in terms of product form, a direct correlation exists between corner radius and product size.

In watches, as discussed previously, this study confirms the curvature bias shown in Bar and Neta's (2006) study, which found that people preferred a rounded watch over a rectangular one. However, both rounded and rectangular watches are popular in the market, so whether both rounded and rectangular watches, or only rounded watches, are considered as prototypical forms is unclear. Nevertheless, this result (short-dashed line in Figure 5) also reveals a preference peak at the fifth curvature level, indicating that the participants felt that this level was novel. Additionally, the eighth curvature level became a local minimum, indicating that the curvature change exceeded the participants' expectations. Finally, a rise occurs at the tenth level, indicating that the change became acceptable again, probably because the form at the tenth level approaches the rounded prototypical form, and fits with the participants' expectations again.

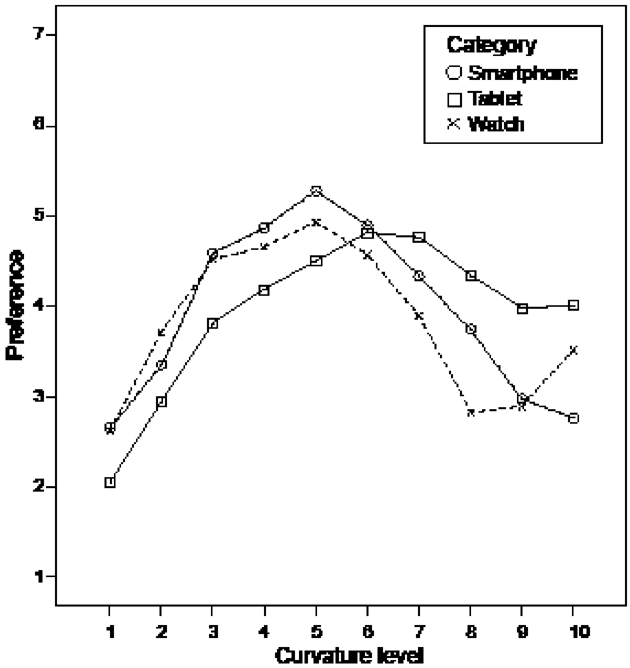

Figure 5. Participants' preferences for the three types of products with different curvatures.

Expertise

Regression analysis results indicate that the correlation between the curvature levels of the stimuli and participants' perceptions of curvature was closer for participants with a design background than for those without one. This finding indicates that participants with a design background had higher sensitivity to variations in the level of curvature on products. Meanwhile, the level of preference of participants with a design background decreased sharply when the curvature exceeded a certain level, while those with a non-design background showed only a small decrease in preference. Different trends were observed between the two types of participants (design background / non-design background) in the level of curvature perceived on two product categories (smartphone and tablet), as shown in Figure 6.

Augustin and Leder (2006) suggest that designers focus more than regular viewers on the overall impression of a product. Experts interested in art are more sensitive than other viewers to product changes, and thus more heavily emphasize high-level design concepts (Leder & Carbon, 2005), such as style (Augustin & Leder, 2006). As shown in Figure 6, although those with a design background had stronger preferences than those without for products with sharper form, they exhibited a sharply decreasing trend after the preference reverse occurred. The preference for products with a higher curvature level among those without a design background decreased only slightly after the peak in preference. In other words, people with a design background are mainly concerned with the overall appropriateness of the style when viewing a product, while people without a design background tend to concentrate on specific characteristics. Hence, individual differences may result in different preferences regarding curvature. When the curvature is gentle, individuals with a design background consider the style unsuitable and their preferences are less affected by the straight shape or the curved shape (Silvia & Barona, 2009). Despite a slight weakening in their preferences, people without a design background retain stronger preferences than those with a design background.

General Discussion

From the perspective of product design, this study explored variations in product size, design versus non-design background, and preference regarding product form curvature. In particular, this study implemented systematic variations in product form without deviation from prototype, and thus implemented different experimental settings from prior investigations. This study contributes to the existing literature on the preference for curvature in several ways.

First, the study confirms that people's preferences for product form and curvature level exhibit an inverted-U curvilinear relationship. This result is in concordance with the findings of Blijlevens et al. (2012). Thus, designers should be encouraged to give a new mobile device a novel form, since this will increase

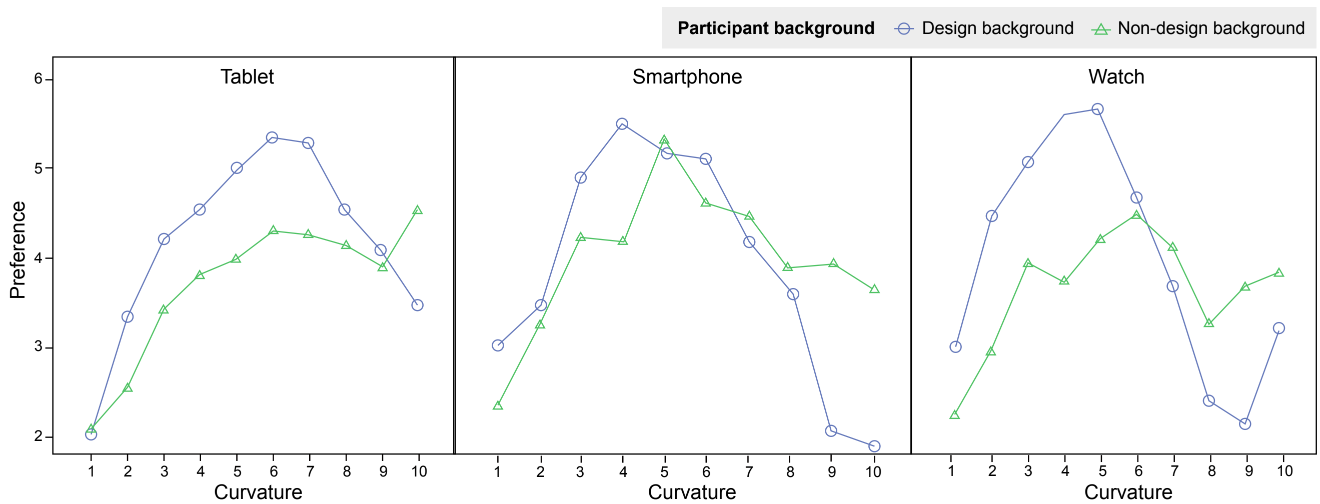

Figure 6. Design and non-design background participants' preferences for three categories of stimuli.

its aesthetic appeal to consumers. However, such changes should also be made with caution so as not to go beyond consumers' expectations. Second, curvature level and product size interact in terms of viewers' aesthetic preferences. Accordingly, designers should consider that the same design feature will be perceived differently. For example, designers might need to increase the curvature level on a tablet if they want to deliver the same curvy feeling as on a smartphone. Third, differences exist between individuals with and without a design background. Participants with a design background were concerned mainly with the overall appropriateness of the style, and were less affected by any specific characteristic. However, participants without a design background were easily influenced by specific features such as angularity.

Limitations and Future Research

Although this study systematically controls the settings of the stimuli to explore the influence of curvature on the preferences of viewers, several questions concerning aesthetic appraisal and the underlying processes remain unanswered. First, the results show that variations in size and in radius of curvature affect people's preferences. However, the increase in size is not systematic in this study. Therefore, the results of this study do not provide a mathematical equation linking radius of curvature to product size. In future studies, experiments can be designed to focus on the relationship between radius of curvature and product size.

Second, the main focus of this study is to discuss people's preferences for product forms in terms of variations in the degree of curvature without deviating from the prototypical shape of the product. The watch was selected as a stimulus to confirm the results of previous curvature bias studies. Because the curvature changes in the watch also change its prototypicality, the watch shows a different preference trend from the smartphone and tablet. However, whether the trend for the watch is caused by one prototypical change (from rounded typical shape to non-typical shape) or two prototypical changes (from rounded typical shape to non-typical shape and then back to square typical shape) is still unknown. Future studies could focus on products like watches that might have two or more prototypical shapes.

Third, all the products were scaled to 75% of their actual sizes during the experiment, and their profile lines were displayed on a screen. This may not completely reflect the feelings aroused in consumers by real-world products. Thus, future studies could address product scale.

Fourth, for this study products were selected based on their front views. However, selecting the profile lines of the front view as stimuli may show effects different from actual products, such as the presentation of three-dimensional materials. Future research could replace the profile lines with 3D effects in order to examine whether the same phenomena still exist.

Consequently, related future studies may test other types of products or focus solely on the equation defining the relations between side length and corner radius. The findings could be applied to interface design or packaging. These aspects are worthy of future study.

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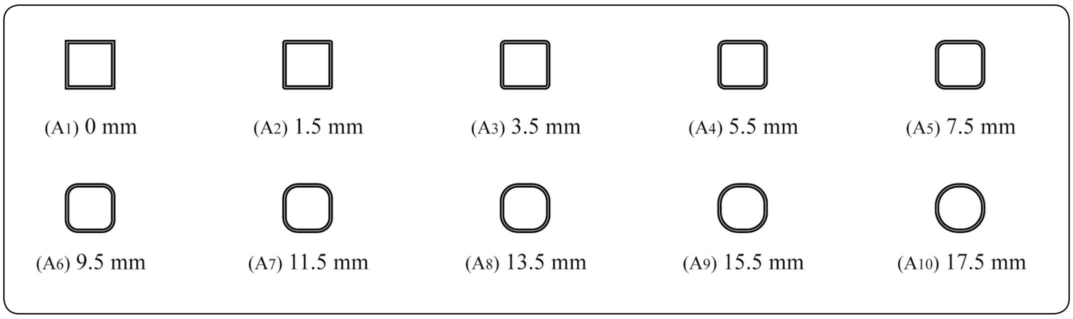
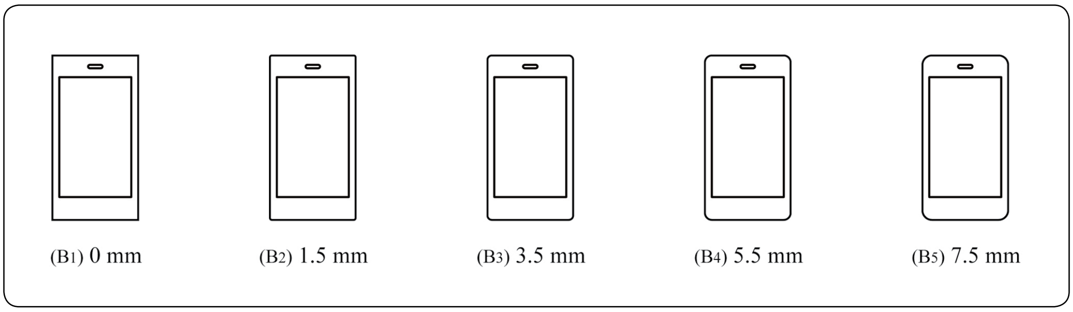
Appendix

Three different products of different sizes—watch, smartphone, and tablet—were chosen as the stimuli for the present study. In order to eliminate preferences caused by color, material, and brand, front views of the products were used. The corner curvatures of the products ranged from a right angle to a gentle curve, and were divided into ten levels: 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. Thus the experiment employed 30 stimuli (10 curvatures × 3 product types = 30), as illustrated below.

A. Watch (38 x 38 mm) with 10 levels of curvature on the corners



B. Smartphone (130.3 x 66.9 mm) with 10 levels of curvature on the corners



C. Tablet (238 x 158.2 mm) with 10 levels of curvature on the corners