*Research Article*

Empirical Studies of the Arts
0(0) 1–17

DOI: 10.1177/0276237419897048
journals.sagepub.com/home/art
SAGE

# A Study of Objects With Smooth or Sharp Features Created as Line Drawings by Individuals Trained in Design

**Marco Bertamini**[1,2] and
**Michele Sinico**[3]

**Abstract**

There is a long history of studies of shape preference using simple abstract two-dimensional shapes. The evidence has confirmed a preference for symmetry, high contrast, and smoothness over asymmetry, low contrast, and angularity. However, the evidence about the role of culture and expertise is inconclusive. We asked a group of 56 expert designers (studying at the IUAV) to draw seven objects on paper and for each provide two versions: a smooth version and an angular version. These stimuli therefore show everyday objects, freely chosen by the authors, drawn with novel shapes. Next, we presented these stimuli to nonexperts. We collected ratings for seven characteristics ("ugly/beautiful, dark/light, complex/simple, heavy/light, old/modern, dangerous/safe, and asymmetrical/symmetrical") from naive observers ($n = 174$). The analysis of the rating data confirmed a link between smoothness and beauty as well as a few other associations. We made the database (772 images) including the average ratings openly available to other researchers.

[1]Department of Psychological Sciences, University of Liverpool, UK
[2]Department of General Psychology, University of Padua, Italy
[3]Department of Architecture and Arts, IUAV (University of Venice), Italy

**Corresponding Author:**
Marco Bertamini, University of Liverpool, Bedford Street South, L69 7ZA Liverpool, UK.
Email: M.Bertamini@liverpool.ac.uk

**Keywords**
aesthetics, smooth curvature, shape

Experimental work on visual aesthetics has a long history. In his 1976 book on aesthetics, Fechner introduced methods to study preferences in the general population. He used this empirical approach to study in detail the Golden ratio. More recently, there has been a renewed interest in testing whether simple properties of the stimuli that can be defined precisely have a universal effect on visual preference (Latto, 1995; McManus, 1980). The evidence in support of the Golden ratio is weak (Bruno, Gabriele, Bertamini, & Tasso, 2014; Höge, 1997; McManus & Weatherby, 1997). However, some other properties appear to have robust effects. Among them, we can mention symmetry as compared with asymmetry (Arnheim, 1974; Eisenman, 1967; Makin, Pecchinenda, & Bertamini, 2012; Rhodes, Proffitt, Grady, & Sumich, 1998), high as opposed to low contrast (Tinio, Leder, & Strasser, 2011), vertical/horizontal as opposed to oblique orientation (Latto, Brain, & Kelly, 2000), natural as oppose to man-made scenes (Kaplan, Kaplan, & Wendt, 1972), and smooth curvature as opposed to angularity (Bar & Neta, 2006; Bertamini, Palumbo, Gheorghes, & Galatsidas, 2016; Palumbo, Ruta & Bertamini, 2015; Silvia & Barona, 2009). This study focuses on the comparison between smooth and angular shapes using drawings of familiar objects.

The beauty of smooth curvature and curved lines can be seen in many examples of visual art (Bertamini & Palumbo, 2015). Moreover, artists such as William Hogarth (1697–1764) have explicitly drawn attention to curvature. In his book (*The Analysis of Beauty*), Hogarth (1753) argued that straight lines have little ornamental value, curved lines begin to be ornamental, and that there is an optimal S-shaped line which he called *line of beauty*. He added that the serpentine line is the *line of grace*, which he described as a wire "twisted round the elegant and varied figure of a cone (p. 39)." Allen (1879) asked whether the preference for curvature is a departure from preference for the simpler and more regular straight line. He suggested that "the straight line represents practical beauty, and the curve ornamental beauty" (Allen, 1879, p. 314).

The importance of curvature was also noted by the Gestaltists. In particular, the famous *takete/maluma* effect is about curved and angular shapes (Köhler, 1929). People associate the word *takete* with angular shapes and the word *maluma* with curved shapes, as confirmed by many later studies (e.g., Kwok, Fantoni, Tamburini, Wang, & Gerbino, 2018; Milan et al., 2013). In terms of associations, early studies about curved lines found that they were rated as sad, quiet, lazy, merry, and gentle. By contrast, angular lines were rated as agitating, furious, and hard (Lundholm, 1921; Poffenberger & Barrows, 1924).

Recent experiments have highlighted a few additional aspects of preference for curvature. Silvia and Barona (2009) investigated the role of experience and the link between preference for curvature and subjective complexity using abstract geometrical shapes. Preference for curved shapes was found even when controlling for subjective complexity. However, there was also a role of expertise. For circles and hexagons, the curvature effect was confirmed only for novices; for irregular polygons, the effect appeared only for experts. Preference for curvature using unfamiliar shapes, however, has bene found in other studies (Palumbo & Bertamini, 2016; Silvia & Barona, 2009; Velasco et al., 2016) including a study with infants (Jadva, Hines, & Golombok, 2010).

In recent years, there has been renewed interest in individual differences and the role of expertise. It has been suggested that experts are less affected by properties of the stimuli and more sensitive to compositional and historical features (e.g., Lundy, 2010; Parsons, 1987). Vartanian et al. (2019) compared experts (architects and designers) and nonexperts on preference for curvature. The stimuli were rich images of internal architectural spaces. Expertise modulated preference in that the preference for curvature emerged using beauty rating in the experts and using an approach-avoidance task in nonexperts. In many studies, including the study by Vartanian et al., the sample size is small. An exception is the study by Cotter, Silvia, Bertamini, Palumbo, and Vartanian (2017) in which they collected responses to irregular polygons from 132 students. The authors found that participants higher in artistic expertise or openness to experience showed a greater preference for curvature. Cotter et al. did not analyze gender, but there is some evidence that openness may correlate with gender. Costa, Terracciano, and McCrae (2001) reported that men scored higher in some facets (openness to ideas) and women on others facets of openness (openness to aesthetics and feelings). It is therefore possible that preference for curvature is higher in females, and they provide a majority of the participants in studies conducted in psychology departments.

Bar and Neta (2006) found a preference for curved shapes using both abstract shapes and images of familiar objects that were manipulated to appear more or less angular. This study was followed up by a study that used functional magnetic resonance imaging to measure activity in the amygdala (Bar & Neta, 2007), a brain area involved in processing fear. There was greater bilateral activation in the amygdala for sharp-angled shapes compared with curved shapes. Bar and Neta (2007) concluded that angles are automatically associated with threat. The universality of a preference for curvature has recently been supported by cross-cultural comparisons (Che, Sun, Gallardo, & Nadal, 2018; Gómez-Puerto et al., 2018).

Curvature has also been studied in the context of product design. An early study was carried out in 1968 by Kastl and Child. They analyzed typography and concluded that round letters are perceived as more pleasant than angular letters. Leder and Carbon (2005) have studied car design and how it has changed over time. Cars evolved to become curvier, compared with the forms popular in the later part of the 20th century. Leder and Carbon also confirmed that more curved interiors are perceived as more attractive. Studying packaging design, and focusing on crossmodal correlations, Velasco, Salgado-Montejo, Marmolejo-Ramos, and Spence (2014) found that rounded shapes and typefaces better express sweet tastes and angular shapes and typefaces better express sour tastes. About the effect of curvature on the user experience, curvilinear forms of internal spaces have the potential to induce feelings of joy, harmony, and well-being (Papanek, 1995) and they also appear pleasant and stress-reducing (Madani Nejad, 2007). Comparing curvilinear with rectilinear simulated interior settings, Dazkir and Read (2012) have found that curvilinear forms are perceived as significantly more pleasant than rectilinear forms. Furthermore, curvilinear interior settings also generated pleasant-unarousing emotions, such as feeling relaxed, peaceful, and calm, more than rectilinear settings.

As we have seen, there have been studies that used very simple abstract shapes, and other studies that have included familiar objects or architectural spaces. There are substantial differences in the degree of shared taste across different visual aesthetic domains. For example, Vessel, Maurer, Denker, and Starr (2018) found that agreement across individuals was higher for naturally occurring domains (e.g., faces and landscape) than artifacts of human culture (e.g., architecture and artwork). Measuring visual preference, Vessel and Rubin (2010) found that abstract images yield lower agreement among observers than real-world images. However, in our study, we did not investigate the role of type of images. Our stimuli were all common everyday objects created by expert designers. In these drawings, unlike in natural objects and other artifacts, the curvilinearity and angularity factors are integrated into the overall aesthetic balance of the product.

In summary, using a large range of stimuli (familiar or unfamiliar) and procedures (ratings of beauty, forced-choice, or implicit measures of preference), the literature shows a robust preference for the smoother version of two stimuli. We take this as the basic phenomenon of study. As we have seen in the review, the stimuli used tend to be either selected from images of real objects or created in the laboratory by some random process (e.g., selecting vertices along a contour). In this study, we took a different approach. We worked within a Department of Design at the IUAV (University of Venice) and asked Master's students to create images of design objects.

The task was to make two versions of each object: one rounded and one angular. The task itself did not mention beauty or preference. This allowed us to collect a large set of images, from a set of authors, and subsequently use these images with naive observers. In the next section, we describe in detail the process of stimuli generation and the data set of images. Examples are shown in Figure 1.

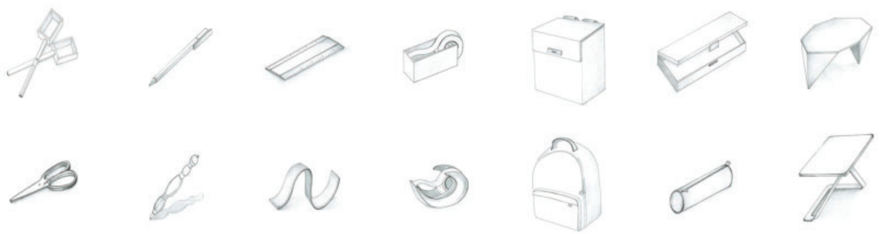

**Figure 1.** Examples of images for seven objects from one author. The top row shows the angular version, and the bottom row shows the smooth version. The full data set is available at https://osf.io/cx62j/.

Using these images, we will then report the results of a study using naive observers. These observers were not expert in design and were from the wider population. Therefore, we will be able to analyze ratings from a large sample, including in particular a fairly balanced number of men and women.

## Image Generation

Fifty-six individuals (25 males, 31 females) took part. They were reading for a Master's degree in Product and Visual Communication Design in the Department of Architecture and Arts at the IUAV (University of Venice) and were enrolled in a course on Human factors. The age ranged from 22 to 27 years.

Each image was drawn on a separate A4 page. The task was to produce images for seven different objects. In addition, for each object, one version of the object was to appear curved ("arrotondato") and the other angular ("spigoloso"). The author also scanned and standardized the digital images. In contrast to naive subjects or artists, drawings by designers are characterized by implicit project constraints, such as the function of the artifact, safety factors, usability, and cost of production (Kavakli, Suwa, Gero, & Purcell, 1999; Lawson, 1980). In addition, designers are also particularly skilled at satisfying both the Congruence Principle for which the structure and content of an external representation should correspond to the structure and content of the desired mental representation and the Apprehension Principle for which the structure and content of an external representation should be readily and accurately perceived and comprehended (Tversky, Morrison, & Betrancourt, 2002; see also Tversky et al., 2003; Van Sommers, 1984).

Each author was asked to produce seven pairs of objects. Two of them created only five pairs and two more created six pairs. Therefore, we have a total of 386 items ($7 \times 52$ plus $6 \times 2$ and $5 \times 2$). As these are pairs of angular and smooth versions of the objects, we have 772 images. Of the 386 items, 87 were drawn with the help of a computer and the rest were drawn freehand. We use the term item to refer to a specific drawing to avoid confusion with the specific object. Different authors may have drawn the same object (e.g., a chair), but these are referred to as different items.

We hope the data set will be useful to other researchers. All images are available on Open Science Framework (https://osf.io/cx62j/). In the data set, we include the following information about the images: author (a unique numerical identifier of the creator), type (smooth and angular), example (a unique numerical identifier of the drawing), object (a label, such as "chair"), a category for the type of drawing (computer generated or freehand), the sex of the author, and the presence or absence of shading in the drawing. In addition, we list file size (in bytes) and the ratio between compressed and uncompressed file (jpeg ratio). Compression ratio has been used in the literature as a measure of image complexity (Forsythe, Mulhern, & Sawey, 2008; Palumbo, Ogden, Makin, & Bertamini, 2014).

## Image Rating

### *Participants*

One hundred and seventy-four individuals (88 males, 86 females) took part in the study and were not the same individuals who created the images. They were naive with respect to any hypotheses until after the data had been collected. The sample did not come from the same population that created the stimuli (they were not students on the Master's degree) and to the best of our knowledge did not have a specific background in art history or art production. The average age was 34 years, and 19 individuals were left-handed based on self-report. The experiment had approval from the IUAV Research Ethics Committee.

### *Design*

It was not feasible to test each individual with all images. Moreover, we decided to avoid that the same item could be seen in both versions (angular and smooth) by an observer. Therefore, every observer saw 25 images of 25 different items. Ten images were chosen for a practice, this part of the procedure was identical for every observer but responses to the practice phase were not included in the analysis. We obtained data from 174 observers, divided in 28 groups. Each group saw different images, and therefore we were able to collect data for 700 of 772 images. Because for each image we have two versions, the items tested were 350. As noted before, there was a constraint on the design so that nobody saw both versions of an item (different versions were used for different groups).

### *Procedure*

Each participant was tested individually. The presentation of the stimuli and the recording of the responses were controlled by a program in Python using the

PsychoPy software (Peirce, 2007). Distance from the screen was not enforced, but at a natural distance of approximately 57 cm all stimuli were 10° of visual angle in height.

Participants were instructed about the use of a rating scale with two end points. They were told that the judgment was personal and subjective, meaning that there was no right or wrong answer. They were also asked again if they had questions at the end of the practice.

The seven rating scales were beauty (ugly/beautiful), lightness (dark/light), complexity (complex/simple), weight (heavy/light), style (old/modern), danger (dangerous/safe), and symmetry (asymmetry/symmetry). The words used in Italian were brutto/bello, scuro/chiaro, complesso/semplice, pesante/leggero, antico/moderno, pericoloso/sicuro, and asimmetrico/simmetrico. Note that the ambiguity about the word "light" referring to both brightness and weight does not exist in Italian. The categories (rating scales) were randomly interleaved, and therefore different participants responded to these in different order. Moreover, the direction of the rating scale was also varied randomly. Therefore, there were two possible directions, the original as listed earlier (e.g., "brutto" on the left) and the reversed one ("brutto" on the right). An example of the rating scale is shown in Figure 2.

### *Analysis*

We carried out a series of mixed analysis of variance (ANOVA) with the following design. The within-subjects factors were Type (smooth/angular), and Direction (original/reversed), and the only between-subjects factor was Sex. Direction refers to one of two ways in which the categories were displayed. Taking ugly/beautiful as an example, original means that the word "ugly" was on the left and "beautiful" on the right, and reversed means the opposite. The seven dependent variables were analyzed separately: beauty (ugly/beautiful), lightness (dark/light), simplicity (complex/simple), weight (heavy/light), style (old/modern), danger (dangerous/safe), and symmetry (asymmetry/symmetry). For each dependent variable, the rating score could range from $-10$ to 10. Therefore, for instance, when ugly was on the left (original direction), the highest possible score for ugly was $-10$ and the highest possible score for beautiful was 10. Although the labels were presented in two directions for the summary statistics and the graphs, we use the original convention. Graphical representations of the difference between the two types (smooth/angular) are shown in Figure 3.

## Results

### *Beauty*

The overall mean beauty score was 0.38 (standard deviation [$SD$] = 5.8) for angular images and 1.01 ($SD$ = 5.6) for smooth images. There was only one

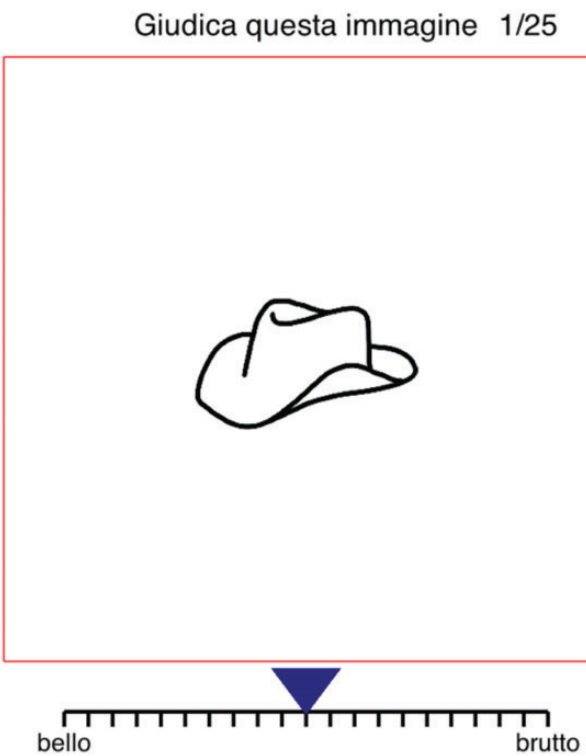


Figure 2. An illustration of the task showing a rating scale for beauty. The stimuli and the categories for the rating scales were presented in random order. The sentence at the top of the screen says: "please judge this image 1/25." This number informed participants of how many more images were left.

significant factor in the ANOVA and that was the type: Smooth images were judged as more beautiful, $F(1, 172) = 13.81$, $p < .001$, $\eta^2 = .07$. We expected a stronger preference for curvature in females, but this was not confirmed.

## *Lightness*

The overall mean lightness score was 2.20 ($SD = 6.2$) for angular images and 2.60 ($SD = 6.2$) for smooth images. There was only one significant factor in the ANOVA and that was the type: Smooth images were judged as lighter, $F(1, 172) = 5.25$, $p = .023$, $\eta^2 = .03$.

## *Simplicity*

The overall mean simplicity score was 2.70 ($SD = 6.0$) for angular images and 3.40 ($SD = 5.7$) for smooth images. There was only one significant factor in the

ANOVA and that was the type: Smooth images were judged as simpler, $F(1, 172) = 11.90$, $p < .001$, $\eta^2 = .07$. Note that the fact that smooth stimuli tend to be perceived as simpler is consistent with the existing literature (Bertamini et al., 2016).

### Weight

The overall mean score on the heavy/light scale was 1.30 ($SD = 6.1$) for angular images and 2.20 ($SD = 5.9$) for smooth images. There was only one significant factor in the ANOVA and that was the type: Smooth images were judged as less heavy, $F(1, 172) = 21.36$, $p < .001$, $\eta^2 = .11$.

### Style

The overall mean score on the modern/antique scale was 1.30 ($SD = 6.1$) for angular images and 2.20 ($SD = 5.9$) for smooth images. There were no significant main effects or interactions in the ANOVA.

### Danger

The overall mean score on the dangerous/safe scale was 2.5 ($SD = 5.6$) for angular images and 3.2 ($SD = 5.4$) for smooth images. There was only one significant factor in the ANOVA and that was the type: Smooth images were judged as less dangerous, $F(1, 172) = 16.38$, $p < .001$, $\eta^2 = .09$. Note that the fact that angular stimuli tend to be perceived as more dangerous is consistent with the existing literature (Bar & Neta, 2016).

### Symmetry

The overall mean score on the symmetry scale was 2.6 ($SD = 6.7$) for angular images and 1.7 ($SD = 6.9$) for smooth images. There was only one significant factor in the ANOVA and that was the type: Smooth images were judged as less symmetrical, $F(1, 172) = 13.07$, $p < .001$, $\eta^2 = .01$.

We explored the relationship between the different categories, and we show the results in Figures 4 and 5. The first set of graphs focuses on how beauty relates to the other dimensions across the items. Here, we can see that more beautiful items were also the items seen as more modern, light (brightness), light (weight), safe, and symmetrical. It may seem paradoxical that symmetry had a positive correlation with beauty given that smooth items were on average more beautiful than angular items but also less symmetrical. This of course is possible and indeed one can see these effects in the last panel of Figure 4. Data for smooth images are shifted toward higher scores of beauty, while in both angular and smooth data sets, there is a positive association with symmetry. It is also

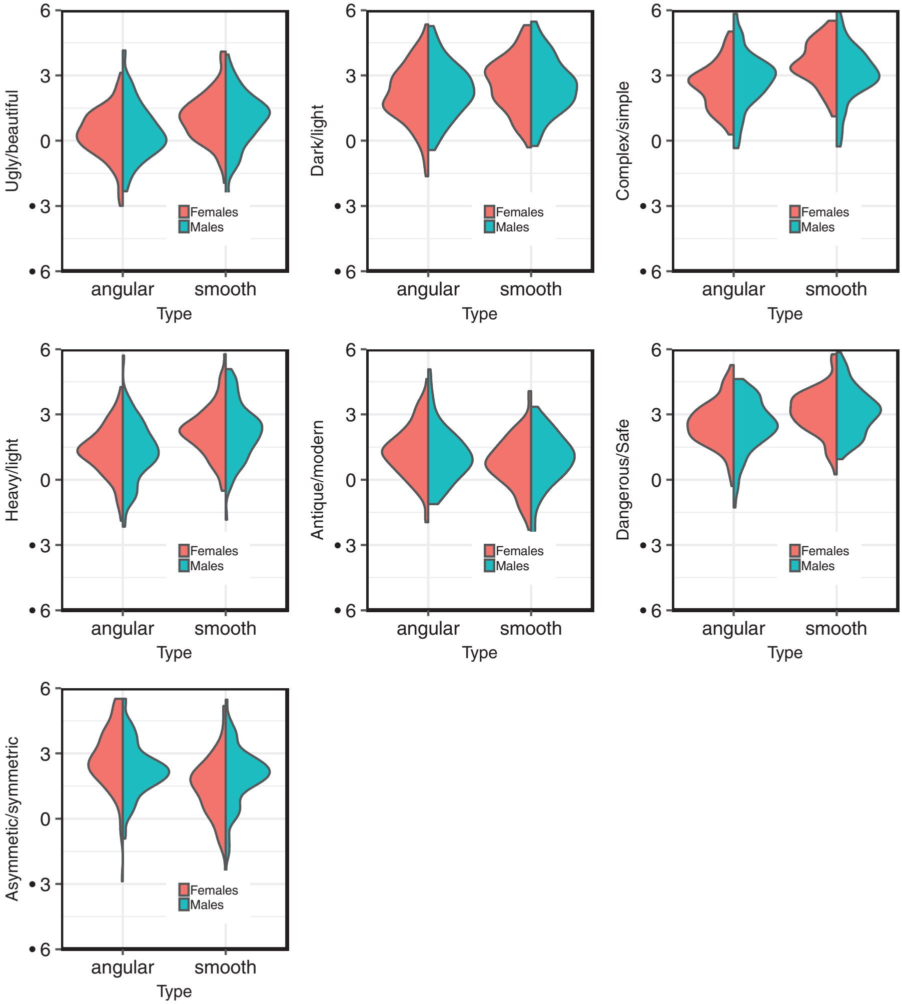


**Figure 3.** Mean rating for all seven categories. The data are presented separately for males and females. We chose to separate the data set in these graphs because it was balanced (88 males, 86 females) and the measures were independent, showing therefore the robustness of the results.

clear from the analyses and from the graph that there was no evidence of any association between ratings on these categories and sex.

Figure 5 shows pairwise correlations (Bonferroni corrected) for the seven rating categories. Therefore, the first row provides similar information to that plotted in Figure 4 but in a different format. With respect to beauty, beautiful was associated with light (weight), safe and symmetrical, and also with simple

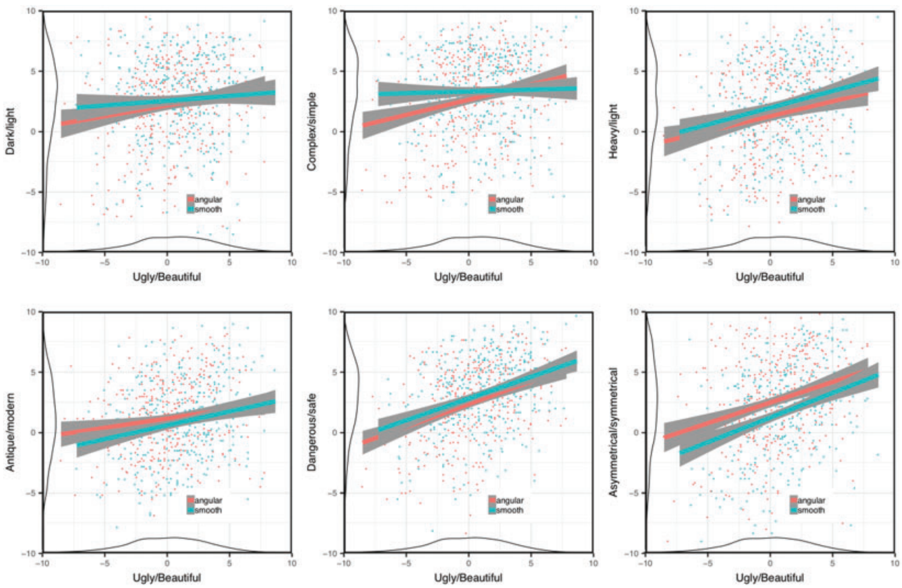


**Figure 4.** Scattergraphs showing the association between the responses to beauty and the responses to each of the other six categories. Each point is one item ($N = 350$), density plots are shown along the axes.

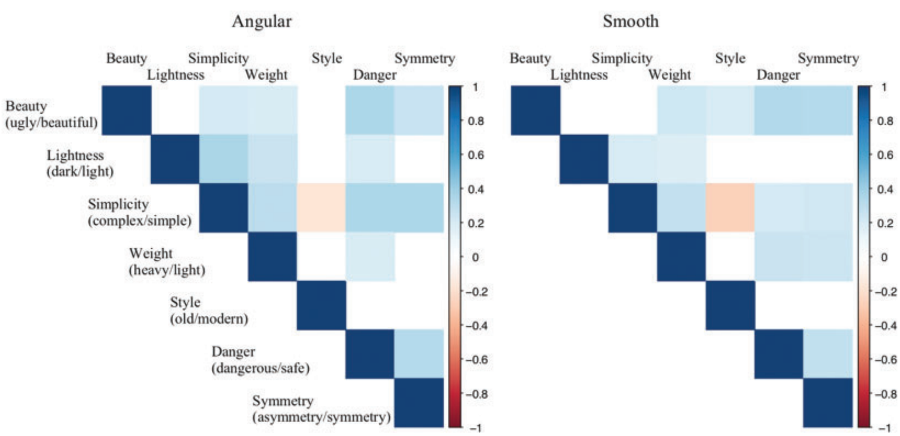


**Figure 5.** Correlations (Pearson's $r$) between the seven categories tested based on responses to the different items ($N = 350$). The correlations are shown separately for angular (left) and smooth (right) stimuli. The blank cells indicate that the correlation was not significant.

but only in the angular condition. The rest of the matrix provides additional information. For example, in the case of ratings of simplicity, higher values were associated with light (weight), old (style), and safe and symmetrical. To analyze the role of complexity in human preference is outside the scope of this research, but it is interesting that simplicity is linked to preference in a way that seems modulated by other factors. This reflects the controversial role of complexity in the literature on aesthetics (Birkhoff, 1933; Eisenman, 1967; Eysenck, 1941). However, to focus on the analysis of curvature, the side-by-side comparison for angular and smooth shapes in Figure 5 shows a similar pattern.

## Discussion

Human preference for smooth curvature is a well-known phenomenon. It is easy to find examples of curvature in works of art and also in objects designed by humans. Preference for curvature does not appear to depend on perceived regularity, complexity, or familiarity (Bar & Neta, 2006; Bertamini et al., 2016; Silvia & Barona, 2009; Tinio et al., 2011). However, in the past, most studies have been limited to either very simple stimuli (like the circles and hexagons in Silvia & Barona, 2009) or familiar objects (like in Bar & Neta, 2006) using small samples, generally from the undergraduate population.

Works of art provide many examples in which artists have used curvature. The artist and writer William Hogarth (1697–1764) explicitly claimed that a smoothly curve line is the line of beauty. There have also been trends toward more curved objects in technology, such as car design. However, smooth curvature is not a necessary property of artwork or material artifacts. Many artworks have predominantly straight lines, for instance, the meander design of ancient Greek pottery (from around 1000 BC) or the neoplastic paintings by Piet Mondrian (1872–1944). In architecture, some angularity may be a matter of technology, but modernist architecture welcomed sharp lines as can be seen in the Glasgow School of Art building by Charles Rennie MacIntosh (1896–1999).

In this study, we worked with designers from a Master's degree in Product and Visual Communication Design at the IUAV. They produced drawings of objects in two versions: rounded and angular. The database is now available for everyone to use and contains a total of 386 pairs of images (772 files). We collected ratings from naive observers about beauty (ugly/beautiful), lightness (dark/light), simplicity (complex/simple), weight (heavy/light), style (old/modern), danger (dangerous/safe), and symmetry (asymmetry/symmetry). Smooth shapes were perceived as more beautiful, less heavy, less dangerous, and less symmetrical. The mean ratings for all categories are also available as part of the database (https://osf.io/cx62j/) for most of the images (700 of the 772). We used a large sample of naive observers ($N = 174$) which had approximately the same number of males and females (88 and 86, respectively).

With regard to symmetry, Silvia and Barona (2009) reviewed several studies and suggested a possible confound between angularity and symmetry in preference tasks. Our results, according to which smooth images were judged as less symmetrical, strengthen the idea that preference for the curvilinear shape does not necessarily reflect its perceived symmetry.

With respect to safety, it is interesting that observers discriminated the object safety directly based on its shape, and they were influenced by smooth curvature. Product safety can be defined as a structural quality, and our results suggest that safety perceived from relational characteristics, as a form of affordance (Norman, 2013), is reinforced by the perception of smooth curvature. From an evolutionary perspective, angular forms are inherently associated with potentially dangerous stimuli, independently of the semantic meaning or familiarity of the stimuli (Bar & Neta, 2006).

Given the large sample of naive observers (88 males and 86 females), it is also interesting that preference for curvature was strong but not associated with the sex of the observer. It is tempting to think that smooth curvature may be associated with femininity, and in part, this is backed up by the observation that a more angular facial shape depends on testosterone level (Perrett et al., 1998; Perrett, May, & Yoshikawa, 1994). Moreover, Cotter et al. (2017) have found an association between preference for curvature and personality and in particular openness to experience. In turn, there is evidence that women score higher in neuroticism, agreeableness, warmth, and openness to feelings (Costa et al., 2001). The link between shape preference and sex is still unresolved in the literature (Humphrey, 1997). For example, studying infants aged 12, 18, and 24 months, Jadva et al. (2010) found that both males and females looked longer at squares, triangles, and stars than circles, rounded triangles, and rounded stars. In our data, preference for smooth curvature of objects was found to be equally strong in males and females.

The origin of the preference for curvature is debated in the literature, one idea is that curvature associated with complex biological forms and therefore nature. Growth processes may give bodies and fruits rounded shapes that humans are attracted to, including secondary sexual characteristics, like breast size, or neotenic features, like rounded faces. A more fundamental possibility is that the visual system is better at processing smooth curvature. Some evidence has recently emerged from perceptual tasks (shape matching) in which curvature was not task relevant. For example, in one experiment, observers had to decide whether two stimuli were the same, and the pair of stimuli were either both angular or both smooth (Bertamini, Palumbo, & Redies, 2019). The results confirmed that smooth curvature was associated with faster responses in basic perceptual tasks like shape matching. Perhaps the visual system is tuned to smooth contours and the ease of processing such stimuli leads to a preference. This would be an example of how aesthetic preferences relate to visual processing, an idea that has been expressed by various authors in different forms such as resonance (Latto, 1995) optimal stimulation of visual modules (Zeki, 1999), efficient coding (Redies, 2007), or fluent perceptual processing (Reber, Schwartz, & Winkielman, 2004).

## Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

## ORCID iD

Marco Bertamini https://orcid.org/0000-0001-8617-6864

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## Author Biographies

**Marco Bertamini** is the director of the Visual Perception Laboratory at the University of Liverpool. His main fields of reserach are visual perception, visual cognition, and the experimental study of visual preference.

**Michele Sinico** is professor of General Psychology at the IUAV University of Venice. His main fields of research are psychology of expression, perception, and design.