The aesthetics of smooth contour curvature in historical context

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Abstract

The fact that curved shapes and curved objects are seen as beautiful and attractive has been known for a long time. Here we discuss the role of curvature with examples from works of art, starting from the earliest paleolithic cave painting and statuines. The strogest theoretical argument for a 'line of beauty' comes from William Hogarth (1759). Recent empirical work has broadly supported the idea that curvature is linked with beauty, although many questions remain about the origin of the effect. An analysis of visual art across the centuries provides support for a curvature preference, but only as one factor that is sometimes absent or sometimes combined with sharp and angular shapes.

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Introduction

Experimental work on visual aesthetics has been very active in recent years, although its origin goes back to the nineteenth century. For a long time researchers have been interested in studying which properties of stimuli make them appear aesthetically pleasing. Gustav Fechner (1801-1887) introduced the basic behavioral methods at the very beginning of the empirical study of aesthetics. One of the phenomena that interested Fechner was the importance of the Golden ratio. Fechner tested this proportion in a number of studies (Fechner, 1876). It is still a matter of debate whether simple aspects of the stimuli that can be defined precisely have a universal effect in visual preference. Such universal factors, if they exist, could be described as aesthetic primitives (Latto, 1995). The large body of empirical evidence in relation to the Golden ratio has not offered much support for the importance of this proportion (Höge, 1997; Bruno, Gabriele, Tasso & Bertamini, 2014; McManus & Weatherby, 1997). Another property of visual stimuli that has been linked to aesthetics is symmetry, both in objects and in abstract shapes (Arnheim, 1974; Makin, Pecchinenda & Bertamini, 2012).

This paper deals with an aspect of visual preference for shapes for which there is robust evidence. This factor is smooth curvature: observers prefer objects and shapes that are smoothly curved to objects and shapes that are angular (Bar & Neta; 2006; Bertamini, Palumbo, Gheorghes, & Galatsidas, 2014; Silvia & Barona, 2009). Curved lines are also associated with more positive concepts (Hevner, 1935; Poffenberger & Barrows 1924). Despite the clear empirical evidence, the phenomenon has attracted less attention than the Golden ratio or symmetry in the scientific literature.

Is the effect of curvature universal? If so it should be possible to identify its influence across cultures and across centuries. What is the origin of the curvature effect and is it supported by an analysis of visual art?

We are going to start the discussion with a clarification of the meaning of curvature in this context. We will use the word curvature to refer to the smoothness in the charge in curvature along a 2D contour or 3D surface. Therefore the opposite of a smooth contour is a contour with discontinuities or very abrupt changes. The 3D and 2D cases are linked because

contours carry important information about solid shape, and tend to be interpreted as rims of surfaces (Koenderink, 1984). A smooth surface is therefore likely to produce a smooth contour as its projection. In addition contour convexity and concavity are also important (for a review see Bertamini & Wagemans, 2013). Work on the aesthetics of curvature has not systematically tested what amount of curvature, as measured for instance by the second derivative, is optimal. Experiments have therefore focused on a comparison between smoothly curved contours and contours that have local discontinuities (angles), as in the case of a polygon (e.g. Silvia & Barona, 2009), or between solid objects with varying degree of smoothness (Leder, Tinio & Bar, 2011). The role of angles is important because one possibility, supported by a study by Bar and Neta (2007) is that observers have a negative reaction to angles, thus displaying a preference for curvature. They suggested that angles signal threat. Taken to the extreme this hypothesis says that there is no preference for curvature as such, and that angles are the causal factor.

It is also worth noting that despite the fact that interest in curvature can be found in many papers, curvature as an aesthetics factor has not been integrated into major theoretical models. To the best of out knowledge, curvature has not been discussed by some of the main scholars that have influenced the development of empirical aesthetics such as Eysenck (1941), Berlyne (1974) or Kaplan (1987).

Another scholar interested in aesthetics was the American mathematician George Birkhoff (1884-1944). He proposed an aesthetic measure based on order and complexity (Birkhoff, 1932). He wanted to test this idea empirically and to do so produced a large set of polygons. These polygons are well-known as Birkhoff polygons. Unfortunately his proposed measure does not correlate particularly well with human responses (Boselie & Leeuwenberg, 1985; Davis, 1936). Less well-known is the fact that Birkhoff also manipulated shapes of vases in a separate dataset (inspired by Chinese vases), trying to achieve balance and harmony (Scha & Bod, 1993). All of these stimuli have smooth curves. A recent work by Reed (2013) used 3D shapes and a genetic algorithm to determine preference. This led to the evolution of a range of vases with shapes similar to those developed by human designers.

Curvature through the Centuries

It is easy to find examples of the use of smooth curvature in visual art. In Figure 1 we provide a selection of seven diverse examples. This list is of course not meant to be exhaustive or representative. Instead this selection provides examples from different historical periods, from paintings, from artifacts and from sculptures. The first example is the *Venus of Willendorf*. This figurine is approximately 10 cm high and was discovered in Austria in 1908 and is now in the Naturhistorisches Museum in Vienna. It was created between 28,000 and 25,000 B.C.E.. The Venus of Willendorf is one of the most famous Paleolithic artifacts and much has been written about it (McDermott, 1996), including by vision scientists that have highlighted the way convexities create distinct parts (Koenderink, 1990). Many authors see the round shape of the female body as a symbol of fertility. It should be pointed out that this is a specimen of a large class of Paleolithic figurines with similar size and form (Soffer, Adovasio, & Hyland, 2000). There are at least one hundred known Venus figurines carved in soft stone, bone or made with clay and fired. The idea of fertility is not unrelated to the idea of creating the most attractive image of a female body. For instance Dixson and Dixson (2012) have argued that, in the cold climate of the prehistoric age, corpulent females were symbols of reproductively successful communities.

Classical art in Europe is strongly associated with Greece. The earliest period of Greek Art was characterized by geometric patterns on vases (between 900 and 700 B.C.). Although these patterns can be simple horizontal bands about the circumference covering the entire vase, the amphora itself is often a beautifully curved object. The following so-called Archaic, Classical and Hellenistic periods saw Greece reach unprecedented levels in culture and art. As a consequence Greece influenced the culture of other countries. In the West, the art of the Roman Empire was largely derived from Greek models. Sculpture had mainly mythical or daily life themes, with life-sized statues starting around 650 B.C. We will take as example one of the most famous classical sculptures. The *Winged Victory of Samothrace*, also known as *Nike of Samothrace*, was created around 200–190 B.C. and can now be admired in the Louvre (see Figure 1). There are three aspects of curvature in the statue: the female body, the detailed flowing drapery, and the beautiful outstretched wings. These features can still be seen today despite damage to the statue.

When we come to consider classic paintings we find a fundamental place for the human form, especially in the Renassaince. Moreover there are also examples in which objects with curved shapes are used for ornamental purposes. For instance Botticelli (1445-

1510) in the *Birth of Venus* (1486) incorporated in addition to the human body other curved objects such as the large shell. Later, shells became also a major theme in Rococo art and design. Figure 1 shows a Rococo chair. Returning to the Renaissance, which has a special place in the history of Western Art, we have already noted that both female and male bodies are central themes. This is often explained as a desire to depict the beauty of nature.

The painting by Van Gogh (1853-1890) shown in Figure 1 was selected not for the subject matter but because it appears that the technique itself in this case was based on curved brash strokes. This can be seen clearly in *Starry Night* (1889).

In the nineteenth and twentieth centuries the aesthetic canon changed radically. A move away from representational art led to much radical experimentation with shapes and colours. For example, the Russian painter Wassily Kandinsky (1866-1944) was influenced by the Bauhaus school, but in his paintings he included, especially in his later works, softer and malleable shapes, sometimes including organic imagery. The famous *Dominant Curve* (1936) is one example where the key term "curve" appears even in the title of the painting (Figure 1). He also wrote about lines and curves, attempting an analysis of the geometrical elements that make up every painting and that produce subjective effects in the observer (in his book *Point et ligne sur plan*, published in 1926).

Figure 1. Examples of curvature
(1) Venus of Willendorf (circa 26,000 B.C.E.)

(2) Horses in the Lascaux cave, France (circa 17,000 B.C.E.)
(3) Nike Statue of Samothrace (190 B.C.)
(4) Birth of Venus by Botticelli (1486)
(5) the French Rococo Louis XV style armchairs
(6) Starry Night by Vincent Van Gogh (1889)
(7) Dominant Curve by Wassily Kandinsky (1936).

The line of beauty

In 1753 the English painter and writer William Hogarth (1697-1764) published a book titled "The analysis of beauty". Based on principles of simplicity, variety, and regularity Hogarth argued that straight lines lack variety and have little ornamental value, that curved lines begin to be ornamental, and that "the waving line, or line of beauty, varying still more, being composed of two curves contrasted, becomes still more ornamental and pleasing" (chapter VII). In addition to this waving line (S-shaped), he further argued that the serpentine line is the line of grace, and is represented by a "fine wire, properly twisted round the elegant and varied figure of a cone" (chapter VII).

Hogarth is therefore of great interest because he has produced a theoretical account of why he thought that curvature is a key factor in visual aesthetics. His analysis was descriptive and he had no empirical evidence to support his intuitions, but nevertheless he was very specific in the amount of curvature that he considered ideal. He drew an S-shaped curve that in his judgment was the ideal curve. This can be seen in Figure 2. Hogarth wrote "*Though all sorts of waving-lines are ornamental, when properly applied; yet, strictly speaking, there is but one precise line, properly to be called the line of beauty, which in the scale of them is number 4: the lines 5, 6, 7, by their bulging too much in their curvature becoming gross and clumsy; and, on the contrary, 3, 2, 1, as they straighten, becoming mean and poor*" (Chapter 10 [49]). This aspect of Hogarth's writing is still waiting for a direct empirical test.

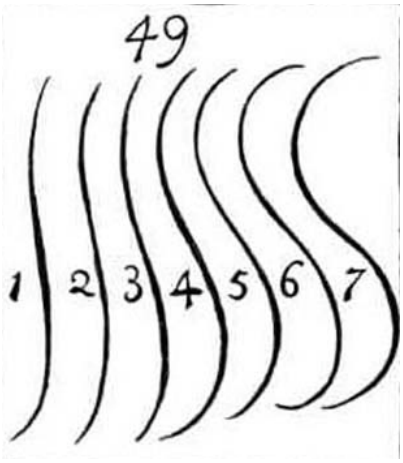

Figure 2. This plate numbered 49 in Hogarth's book shows examples of curved lines. In the opinion of the author the 'line of beauty' is line number 4.

Curvature and nature

The description of the female body has been central to art. Some aspects of what is considered attractive have changed over the centuries while others have remained constant. The Venus figurines such as the Venus of Willendorf, may represent a link between curvature in the body, especially the female body, and wealth (availability of food) as well as fertility. In the bible we can find this passage, which is part of a dialogue between lovers: "*Your navel is a bowl well-rounded with no lack of wine*" (Song of Songs, 7, 3, translation based on The New Jerusalem Bible published in 1985). Similar reference to roundness and curvature can be found in all erotic literature, for instance D. H. Lawrence wrote in *Lady Chatterley's Lover (*1928): "*He watched the beautiful curving drop of her haunches. That fascinated him today. How it sloped with a rich down-slope to the heavy roundness of her buttocks!*".

It is possible to argue that the curvature of contours in the shapes of humans and animals is simply necessary to describe the objects. Animal bodies, such as a horse, have a broadly curved back and muscles in the neck and legs that are smooth and curved. Therefore reference to round shapes in literature and visual art may simply be the consequence of the properties of biological forms. However, curves such as those of the Venus of Willendorf appear exaggerated (see Figure 1). Another example in the 20th century can be found in the style of the Colombian artist Fernando Botero (1932-to present), also known as Boterismo. Botero represents his subjects, human bodies or objects, with extreme curved lines and overstated rounded shapes giving the impression of a caricature to the figure.

The phenomenon where one feature is liked even more when it is present to a greater degree than in the original is sometimes referred to as "peak shift". Ramachandran and Hirstein (1999) have listed peak shift as one principle of aesthetics, however they did not mention curvature. With respect to the horses and bulls in the Lascaux cave, the scale is hard to appreciate in photographs. It is worth noting that some of these animals are several meters in length, and therefore the curves of the animal could not have been produced by a single hand stroke. Instead great care was taken to produce a long smooth contour.

Complex curved shapes such as spirals can also emerge in nature as a result of morphogenesis. This phenomenon was described in great details by the mathematical biologist D'Arcy Thompson (1860-1948) in his book "*On growth and form*" (1917). The spiral shell of a snail is a well-known beautiful example of morphogenesis based on varying rates of growth in different directions.

Humans have also strong preference for certain landscapes. In general what is found pleasing is a natural landscape, although it is not easy to establish exactly what features of a natural environment are critical (Kaplan, Kaplan, & Wendt. 1972; Purcell Lamb, Mainardi Peron & Falchero, 1994; Ulrich, 1981). Orians (1986) for instance has linked the landscape, which humans appear to prefer, to the savannah landscape in which they have evolved. However, in general natural landscapes do contain hills, mountains and rivers that from a distance appear to curve smoothly. This may be a consequence of erosion, a phenomenon already clear to Leonardo da Vinci: "*water gnaws at mountains and fills valleys. If it could, it would reduce the earth to a perfect sphere*" (Codex Atlanticus, 185v).

Angles and straight lines in visual art

The selection in Figure 3 is meant to counterbalance the selection in Figure 1. Although examples of curved shapes are easy to find, examples of straight lines and angles are also present in many works of art across the centuries. The first two images are examples from possibly the oldest cave with extensive rock art, the Chauvet Cave in the Ardeche region of southern France. The age of these drawings is estimated to be between 30,000 and 32,000 B.C.E. The first image has many points used to describe the horns of a deer. The second has a

rhinoceros with a very pointy horn. These are cases where curvature is mixed with sharp points, and it could therefore be argued that they support the importance of both.

By contrast, the weapons in the rock art (Valcamonica, Italy) have no curvature, but one could argue that they represent a faithful description of simple objects. However, within this large body of rock art there are also other rectangular shapes that are not well understood, although generally are believed to represent fields (Arcà & Fossati, 2002). Much clearer is the fact that for centuries Arabic geometrical art has produced complex patterns many of which had no curvature and some were only combination of straight lines. Even more explicit was the position in the 20th century of the school known as Geometric Abstraction. They worked within reductive constrains of abstraction (primary colors, uniform ground and grid lines) because they saw simple geometry as an alternative to the representational art of the past. Perhaps the most easily recognized artist in this school is Piet Mondrian (1872 -1944). Figure 3 shows a representative painting titled "*Composition No. 10*". Mondrian in his later works focused on horizontal and vertical lines. He claimed that "*Vertical and horizontal lines are the expression of two opposing forces; they exist everywhere and dominate everything; their reciprocal action constitutes life*" (as quoted in Seitz, 1983). Curvature was therefore entirely excluded from this program.

The fact that some famous artists, including Mondrian, have developed styles based on straight lines and not smooth curvature is a problem for the idea that curvature has universal appeal. On the other hand one has to remember that the aesthetic experience is often a complex combination of factors, including fascination (capture of attention) and appraisal of the symbolism (cognitive engagement) (Marković, 2012).

We would like to make one final point about the rock art from the Chauvet Cave. In the two examples shown in Figure 3 it appears that the drawings are far from realistic reproductions of natural shapes. The horn of the rhinoceros in particular is almost a half circle. This horn is much longer than it would have been the case even for prehistoric specimens of this large animal. Therefore the very long curve of the horn is an explicit choice made by the artist.

Figure 3. Examples of sharpness

(1 and 2) Details from rock art in the Chauvet Cave, France, circa 30,000 B.C.E.

(3) Rock art from Valcamonica, copper age. The drawings included representations of huts, wagons, harvests and weapons. Daggers with sharp points are shown in the detail.

(4) Arabic art, ceiling of the tumb Hāfez, Shiraz (modern Iran), XIV century.

(5) Ceiling panel in wood with geometric motifs, early XIV century. From the Museu Nacional d'Art de Catalunya, Barcelona.

(6) The spires of the Milan Cathedral, Milan, Italy. Started in 1386 and completed in 1965.

(7) Kazimir Malevich (1879- 1935) Suprematist Composition, 1916

(8) Piet Mondrian (1872 -1944) Composition No. 10, 1939-42.

We have mentioned the human body as an example often described as having curves and round parts. The case of our own species may be special in terms of physical appearance. Adults have traits that are more often associated with the young in other primate species. This phenomenon is known as neoteny. Neoteny can be defined as the retention in the adults of juvenile traits. This may result from a slow or delayed development of the organism. What is relevant is the specific list of neotenic traits. This list includes less body hair, round head, flattened face, and round and large eyes. Overall these traits make the body more round, as can be seen in the young of most mammals. It has been argued that the retention of these traits has emerged in humans at least in part because of sexual selection. There is evidence in fact

that neotenic traits appear more attractive to both men and women (Gould, 1980; Perrett et al. 1998; Penton-Voak, Jacobson, & Trivers, 2004).

Curvature and artifacts

Most of us are familiar with computer-generated shapes, created using vector graphics applications such as Illustrator or Inkscape. There is an interesting history of how the tools to make curved shapes have evolved and it has to do with car manufacture. A mathematician working for the French car-maker Renault developed what are now familiar as Bezier curves. These curves had been described before but Pierre Bezier (1910-1999) used simple equations so that smooth curves could be easily drawn on a computer screen using a mouse and a set of control points (see Figure 4). The technique produced beautiful functions and the underlying principle is one of averaging two tangents defined by control points that the user can move and manipulate.

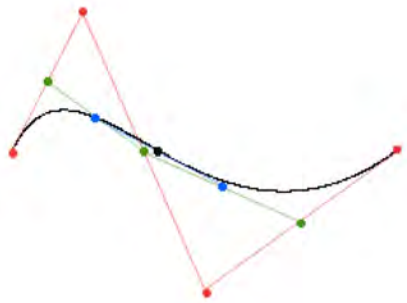

Figure 4. Example of a Bezier curve (black) with four control-points (red). This example is from http://cubic.org/docs/bezier.htm

An early empirical study on preference for curvature in design was reported in 1968 by Kastl and Child. They studied typography and found that round letters were seen as more pleasant than angular letters. More recently, Leder and Carbon (2005) have considered the changes of taste in car design. Cars have become more curvy in recent years, as opposed to the straight lines of the late ‘80s and ‘90s. Leder and Carbon have also collected empirical data and confirmed that more curved interiors were judged as more attractive.

There are also many examples of architects testing new possibilities for biologically inspired buildings, in the Art Nouveau, the Modernist and the neo-Gothic styles. Perhaps the

best examples of this organic style come from Antoni Gaudí (1852-1926). A more recent example is the new fruit and vegetables market in Rotterdam, opened in 2014, with an 11-stories high round arch.

Conclusion

We have seen many examples of curvature in works of art and more generally in objects produced by humans. Most observers agree that curved shapes are more attractive than angular shapes. This has been confirmed empirically with both familiar and abstract shapes and controlling for other factor such as perceived complexity (Bar & Neta; 2006; Leder et al., 2011; Silvia & Barona, 2009). Works of art provide many examples in which artists have used curvature. There have also been trends towards more curved objects in technology, such as car design. It is, however, difficult to use historical trends and separate evidence from universal principles of aesthetics from taste and culture. Overall, it is likely that a preference for curvature exists but that curvature is not a necessary feature and beautiful patterns in art, in material artifacts, and in nature do exist that contain only straight lines. The origin of the preference for curvature is debated in the literature, but it is likely that curvature is linked to associations with complex biological forms.

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