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Fechner's Aesthetics Revisited *

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Abstract

Gustav Fechner is widely respected as a founding father of experimental psychology and psychophysics but fewer know of his interests and work in empirical aesthetics. In the later 1800s, toward the end of his career, Fechner performed experiments to empirically evaluate the beauty of rectangles, hypothesizing that the preferred shape would closely match that of the so-called 'golden rectangle'. His findings confirmed his suspicions, but in the intervening decades there has been significant evidence pointing away from that finding. Regardless of the results of this one study, Fechner ushered in the notion of using a metric to evaluate beauty in a psychophysical way. In this paper, we recreate the experiment using more naturalistic stimuli. We evaluate subjects' preferences against models that use various types of object complexity as metrics. Our findings that subjects prefer either very simple or very complex objects runs contrary to the hypothesized results, but are systematic none the less. We conclude that there are likely to be useful measures of aesthetic preference but they are likely to be complicated by the difficulty in defining some of their constituent parts.

Keywords

Fechner, history, aesthetics, beauty, shape, form

1. Introduction

Widely respected as a founding father of experimental psychology and psychophysics, toward the end of his career, Fechner also made a rather significant contribution to the field of empirical aesthetics. His curiosity with the oft-worshiped golden section (Fechner, 1865, 1871, 1876) and the authenticity questions surrounding the Holbein Madonna (Fechner, 1876) was the beginning of a significant movement whose goal was to empirically investigate art and aesthetics. Of course, structured inquiry into the questions of beauty and aesthetics can be found as far

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back as the works of Plato and Aristotle. Fechner was aware of other efforts to define beauty and its elements, such as Hogarth's 'line of beauty' (Hogarth, 1873), as seen in Fig. 1 (Barasch, 2000). Nevertheless, Fechner's was the first effort to empirically and psychophysically parameterize the elements of beauty.

One of the ongoing fundamental problems in empirical aesthetics is the definition and discovery of appropriate metrics that can be used to evaluate artwork. McWhinnie (1965, 1968, 1971) provides a somewhat older review of the topic and Gibson (1975), Gibson and Pickford (1976a, b) provide an interesting discussion of the pros and cons of such an endeavor. To make empirical aesthetics a truly psychophysical enterprise there must be a meaningful way to compare the artwork with subjects' ratings, preferences, and evaluations.

The golden ratio (sometimes called the 'golden section' or the 'divine proportion') is a well-known geometrically-oriented metric that, for thousands of years, has been thought to possess special aesthetic properties. The ratio,

$$\frac{1+\sqrt{5}}{2} \approx 1.61803, \tag{1}$$

typically denoted by the symbol φ, appears in artistic artifacts that date back as early as 440 BC with the construction of the Parthenon (Hemenway, 2005) as well as various locations in nature, such as nautilus shells and sunflower seeds (Ghyka, 1977).

In his rectangle study, Fechner found peak pleasingness with rectangles possessing the proportions of the golden section. Alas, there has been a terribly mixed bag

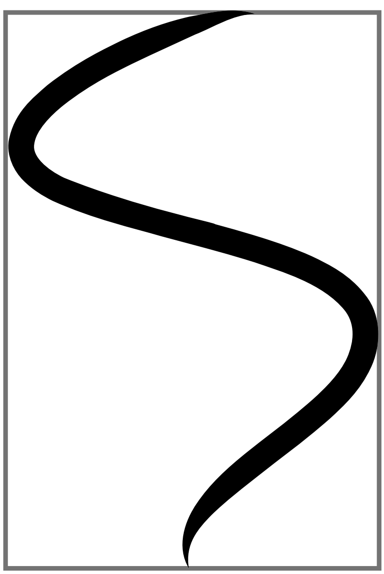

Figure 1. Hogarth's *line of beauty*, an 's'-shaped curve. Here we have scaled it to have the proportions of the golden ratio.

of results when attempting to replicate these findings (see Höge, 1997, for an extensive review). The most recent findings seem to suggest that Fechner's results were anomalous and/or due primarily to methodology (e.g., Green, 1995; Höge, 1997). Of course, this has not put the question to rest (e.g., Dio *et al.*, 2007).

Furthermore, we would contend that it is somewhat difficult to assign a precise aesthetic valuation to a simple rectangle based solely on its proportions, and in isolation from all other contextual information. It is rare to observe a debate over the appeal of a simple four-sided shape, yet, as is well known by experimental psychologists, the nature of the demand characteristic is such that subjects *will* report some preference in these experiments. Though not reported by Fechner, we suspect that, even if the effect of the golden section is real, its effect size is somewhat limited by other factors.

There are certainly other metrics that can be used as a hypothetical model for aesthetic choice. One frequently posited metric is that of *complexity* (see Berlyne, 1968, 1971, 1974; Birkhoff, 1933; Boselie and Leeuwenberg, 1985; Leeuwenberg and Helm, 1991, for some examples).

Berlyne suggested that the aesthetic value and pleasurableness of a stimulus starts at a relatively indifferent level, then increases as a function of complexity up to a certain level, then decreases and becomes more unpleasant as complexity increases. This theory is clearly inspired by the ideas of Wundt (Wundt, 1874) with respect to stimulus intensity rather than complexity (see Fig. 2). This relationship has gained further currency within the field of robotics, concerning the desired realism of humanoid robots, known commonly as *The Uncanny Valley* (Mori, 1970/2005; Pollick (in press); Tondu and Bardou, 2009).

The mathematician George Birkhoff extended the notion of simple complexity to include another factor, order:

$$M = \frac{O}{C}. \tag{2}$$

In this scenario, complexity, C is thought of as attentional 'effort' while order, O, takes on a role as the amount of 'harmony' or symmetry in the object, their ratio,

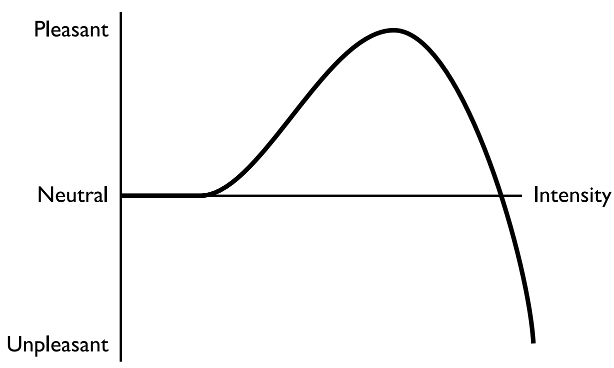

Figure 2. The Wundt curve, an inspiration to Berlyne and others with respect to complexity and preference.

yielding the aesthetic measure, M. There is a certain appeal to this extension — the idea that complexity and the *potential* for complexity are somehow in balance. Still, as with complexity, 'order' has its own definitional difficulties.

What follows is a simple experiment in the spirit of the Fechner's rectangle study — using three-dimensional objects with greater visual and structural complexity.

2. Experimental

2.1. Method

2.1.1. Stimuli

Fifty randomly-shaped, smoothly-curved virtual objects (5 sets of 10 objects) with varying levels of complexity were created using procedures developed by Norman *et al.* (1995). To produce each object, a sphere was sinusoidally modulated in depth (i.e., along the z-axis). The object was then rotated randomly about each of the three Cartesian coordinate axes and modulated in depth (sinusoidally) again. This process was repeated a number of times to create the final object. We manipulated the complexity of the objects by varying the number of iterations, which ranged from 2 (producing the least complex object in each set, object 1) to 31 (producing the most complex object in the set, object 10). The magnitude of the modulation in depth was constant at each iteration for all objects. The surface of each object was defined by the positions and orientations of 8192 triangular polygons (there were 4098 unique vertices). One set of 10 stimulus objects is shown in Fig. 3.

We used the variability in vertex distance (across all 4098 vertices) from the center of the objects as a measure of complexity (see Fig. 2 of Norman and Raines, 2002). Consider a sphere, the simplest globally-convex object. For a sphere, there is no (i.e., zero) variation in vertex distance from its center; the standard deviation of vertex distances is zero. Next consider a potato: its shape is more 'complex' in that there is more variability in the distances from its center to each surface location (i.e., there is a larger standard deviation of surface distances). In comparison, the shape of a bell-pepper is even more complex, in that there is even more variation in the surface distances from its center. All of our objects have the same overall size (the mean vertex distance was approximately 6.7 cm for all objects). However, the complexity of our objects varied widely. For each of our five sets of ten objects, the least complex object (object 1) possessed a standard deviation (of vertex distances) of 0.2 cm, while the most complex object (object 10) possessed a standard deviation of 1.1 cm. Intermediate surface complexities possessed intermediate standard deviations.

The objects were rendered with texture and Lambertian shading. The texture resembled red granite and the shading was produced using OpenGL's standard reflectance model, with an ambient component of 0.3 and a diffuse component of 0.7; the specular component was set to zero, simulating matte surfaces. The ob-

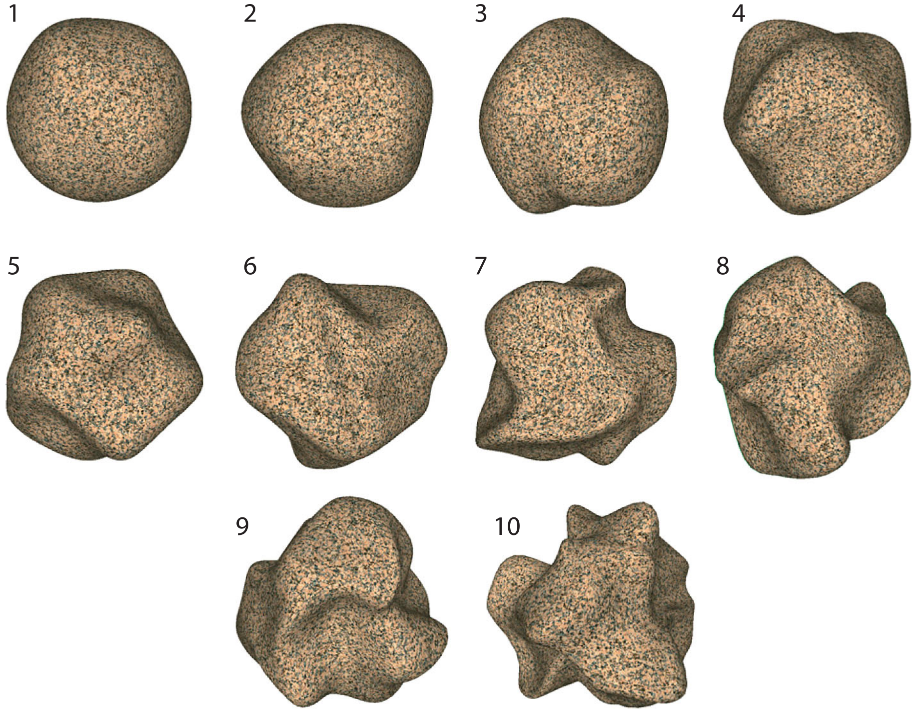

Figure 3. An example stimulus set, ordered by complexity. This figure is published in colour online, see http://www.brill.nl/sp

ject surfaces were illuminated by a simulated point light source at infinity that was coincident with the observer's line of sight.

The stimulus displays were rendered by a dual-processor Apple Power Macintosh G4 computer using OpenGL. Four random spatial arrangements of the ten objects for each set were created and printed, in color, on white paper. There were thus a total of 20 stimulus sheets, each depicting a different spatial arrangement of one of the five sets of ten objects.

2.1.2. Procedure

Each observer was shown one of the five sets of ten stimulus objects. One of the four spatial arrangements of that object set was chosen at random. We used Fechner's method of choice (Fechner, 1876/1997). The observers were asked to indicate which of the objects possessed the most attractive (i.e., most aesthetically pleasing) 3-D shape. The observers were given as much time as they needed to make their judgment.

2.1.3. Subjects

Two-hundred observers (101 males and 99 females) participated in the experiment. All had normal, or corrected-to-normal vision.

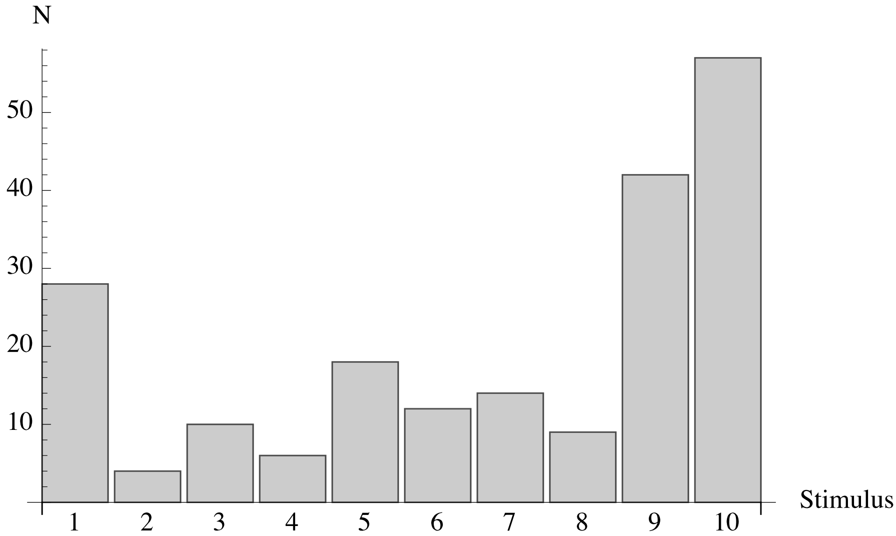

Figure 4. Each bar in the histogram indicates the number of times a given stimulus was selected as the most attractive/aesthetically pleasing. Object complexity increases along the x-axis.

2.1.4. Results

The results are shown in Fig. 4. Each bar in the histogram indicates the number of times a given stimulus was selected as the most attractive/aesthetically pleasing. Object complexity increases along the abscissa. As can be easily seen, performance was decidedly not random, $\chi^2 = 134.7$ ($p < 0.0001$), with the two most complex objects garnering the greatest preference, followed by the simplest object. There was no effect of object set or gender on preference (both $p > 0.1$).

This result runs counter to the simple complexity-based predictions and is, in fact, the inverse of such a prediction. Factoring in an 'ordering' parameter that emphasized symmetry (as one possible factor) would only affect the results slightly. The geometric symmetry decreases with object complexity with these object sets. We constructed one such measure, based on a method proposed by Beran (1968) for testing the uniformity of spherical distributions. The Gauss map (see Note 1) of a symmetrical spherical object will be uniformly distributed. As the spherical object becomes more asymmetric (especially in the way that our stimulus generation procedure distorts them) the Gauss map will exhibit clusters of normals and regions relatively devoid of them. The calculation of this hypothetical M is shown in Fig. 5 for our stimuli. Comparing this predicted result to the actual results shown in Fig. 4 accounts for the preference of the most simple stimuli but not for the most complicated.

One possible explanation for the discrepancy of our results with those predicted by the Berlyne/Wundt hypothesis might be that our range of stimuli did not feature objects of sufficient complexity to drive preference toward the middle. While this is certainly possible, we would suggest that, since the entire range of stimuli were

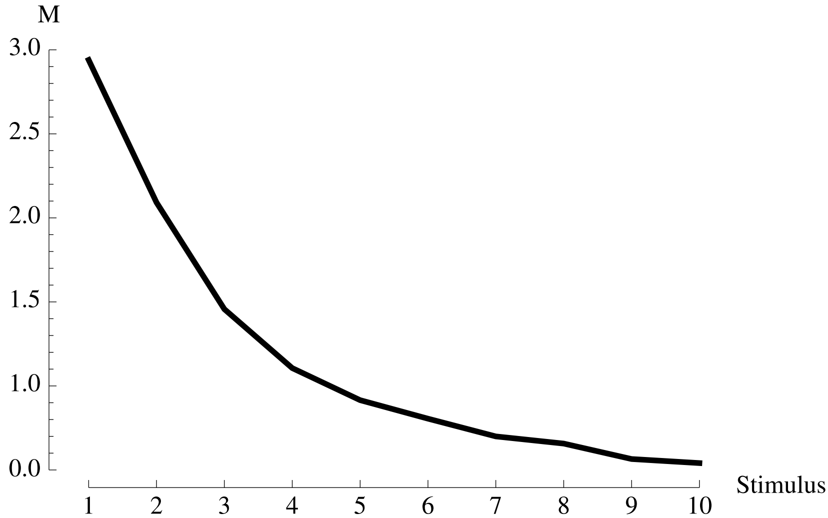

Figure 5. Calculations of *M ala* Birkhoff, using an ordering calculation for *O* based on the distribution of each stimulus' surface normals relative to those of a sphere, and a complexity *C* based on the average displacement of the surface from that of a sphere. Comparing this predicted result to the actual results shown in Fig. 4 accounts for the preference of the most simple stimuli but not for the most complicated.

presented simultaneously, the subjects were able to easily calibrate their judgement against the full range of available complexities. Additionally, there are very few natural objects that possess a complexity greater than our maximally complex object.

3. General Discussion

We believe that much of the problem with applying a metric to beauty comes from the simultaneous interplay of the *denotative* and, more significantly the *connotative* properties of artwork. While the denotative properties are usually clear cut and easily discernible by the viewer, the connotation is a more private event that may be vulnerable to very large individual differences.

For example, there are numerous examples in the art world of the notorious 'blank painting' but we contend the aesthetic appeal of such works lies more in their connotative value — information that is not completely conveyed by the work itself but is suggested in addition to its literal interpretation. For example, the shape of the 'C3' series Corvette, manufactured from 1968 to 1982, is sometimes said to be implicative of a reclining nude woman (see Note 2). Clearly the car was not a literal expression of this shape, but rather, only suggestive of it. For this study we restricted ourselves to the denotative or literal values of the artwork under examination, but the effect of connotation should not be underestimated. Indeed, several subjects responded that the objects reminded them of other, real objects (hearts, various parts of human anatomy, faces, rocks). Any emotional attachment to such denotation may sway an observer toward or away from a particular stimulus.

In our study, the most complex objects were preferred, followed by the most simple. This runs counter to several existing theories of aesthetic choice. Of course, the notion of complexity is a difficult one. By some definitions, such as description length, our objects possess the same or similar complexity, whereas by others, such as the variability-based metric used, they fall into a naturally-appearing progression. Adding other factors to normalize the complexity, such as order, further complicates the matter. Our symmetry measure helped to explain the observers' preference for the simpler objects, but is totally contrary to our findings of preference for the most complex objects.

Lastly, demand characteristics clearly come into play. It is interesting to note that, across 200 subjects, not a single one refused to pick a preferred object, no one complained that they couldn't do the task. In fact, some subjects ruminated significantly, trying to reduce their choice to a single object.

Along with others who seek empirical explanations for aesthetic phenomena, we believe that the problem is tractable. Clearly, our results and the results of others are not random — there is structure to many of the findings. We simply must carry on Fechner's quest to find the right metrics to explain it.

Notes

1. This is essentially, the mapping of an object's surface normals onto a sphere.
2. It should be noted that the Corvette is manufactured in Bowling Green Kentucky — home of Western Kentucky University and two of the authors.

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