Empirical aspects of symmetry perception

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'Take it — to the limit — one more time'

The Eagles

This Special Issue is the second of a pair devoted to the human perception of symmetry relations, the first published collection of articles on this topic. As is evident from the preceding companion issue, the division that had to be made between theoretical and empirical approaches to the topic for the two issues is artificial, intended merely as a grouping principle for the papers submitted. The present contributions are those that emphasized empirical characterization of some aspect of symmetry perception, although many are placed in a clear theoretical framework.

Symmetry is a general concept that refers to any manner in which part of a pattern may be mapped on to another part (or the whole pattern onto itself). Symmetries of various kinds play a fundamental role in both the structure of the physical universe and, in a different form, our interactions with it on a human scale. Early art and architecture offer some insight into the role of symmetry in human perception, suggesting that repetition (translational symmetry) was perhaps the earliest to be aesthetically appreciated. This is evident as much as three thousand years ago in the ranks of repeated figures of terracotta warriors in the tomb of Emperor T'sin, the founder of China, in the repeated profiles of the Persian bas-reliefs of the era of King Xerxes, and in the wall-paintings of the Egyptian pyramids. Remarkably, the mirror symmetry of the human face was hardly ever depicted in this era, although the monumental architecture of its palaces and tombs are replete with both mirror symmetry in the structure of the buildings and repetition symmetry in their ornamentation such as colonnades and battlements. In general, then, symmetries of design have long been widely incorporated into human artefacts, as is amply documented in Symmetries of Culture by Washburn and Crowe (1988), for example.

WHY STUDY SYMMETRY PERCEPTION?

As the preponderance of papers in this issue attest, mirror symmetry is the type that seems to hold the most appeal for perceptual investigation, but does it offer a particular benefit for the analysis of pattern-recognition processes? Most studies in
pattern recognition are based on a past memory of the recognized object and therefore deal with the nature of representation in memory. Symmetry perception is distinct, however, in that it is based on a comparison of representation in immediate perception rather than memory. A memory of one part of the image is not required to recognize the similarity of another part, although memory may be activated during the task. It is the representation of the matching patterns after taking the requisite symmetry transform into account that is the crucial aspect of the recognition process. The immediacy of this process in nonfamiliar (randomly generated) images, as reported in the literature from Julesz (1966) to the present collection, militates against a significant role for memory in the task. Thus, the symmetry paradigm allows analysis of an aspect of complex pattern recognition that is difficult to access by other techniques.

There is significant evidence, reviewed in the contribution by Wagemans, that mirror symmetry has a special status in human perception in comparison with other types (such as translation or rotation symmetry). Why this should be the case may be evaluated in terms of the environment in which our visual system evolved. Mirror symmetry of the objects that we encounter usually betrays the presence of living organisms, for one of several reasons. Inanimate objects, consisting predominantly of rocks and geological formations, generally exhibit no particular symmetry. Crystals may be a special case in this regard, but even then it is rare to find an isolated object consisting of a single crystal with an identifiable symmetry axis. It is only on a non-human scale of analysis that inanimate objects are limited by symmetry constraints. Microscopically, of course, atoms have pervasive symmetries, although these are already delimited by the molecular level. Crystals then constitute an intermediate ('miniscopic') level at which the molecular symmetry is expressed in magnified form. On an astronomical scale, symmetry is resuscitated by the gravitational constraint in the form of pronounced spherical symmetry, together with examples of radial and spiral symmetry in conglomerations of astronomical objects.

Animals that move linearly through the environment always are formed with an axis of mirror symmetry aligned with their typical direction of movement. This design is an obvious adaptation to avoid asymmetries that might cause a bias from the axis of movement. Any tendency to drift to the left or right would create difficulties in orienting and navigating during reduced cue situations (locomoting at night or in tall grass, for example). It seems that it is the motion constraint that is the limiting factor (rather than some inherent genetic property, for example) because only external parts of moving organisms are symmetrical. Internal organs, such as brain, heart, liver, and intestines, may exhibit substantial asymmetry as long as the external envelope conforms to the constraint. It is interesting to note that the design of fast-moving vehicles such as cars and planes adheres to the same symmetry constraints, with exterior mirror symmetry but lateralized placement of internal components such as the steering wheel and driver. On the other hand, animals that do not locomote consistently through the environment, such as starfish and limpets, or that drift or pulse through it as do plankton and jellyfish, do not conform to the bilateral symmetry constraint but typically have either cylindrical or multifold symmetry.

A striking feature of vertebrate animals is that, with rare exceptions such as fingers, they have no symmetries other than bilateral (absence of radial, rotational, repetitive,