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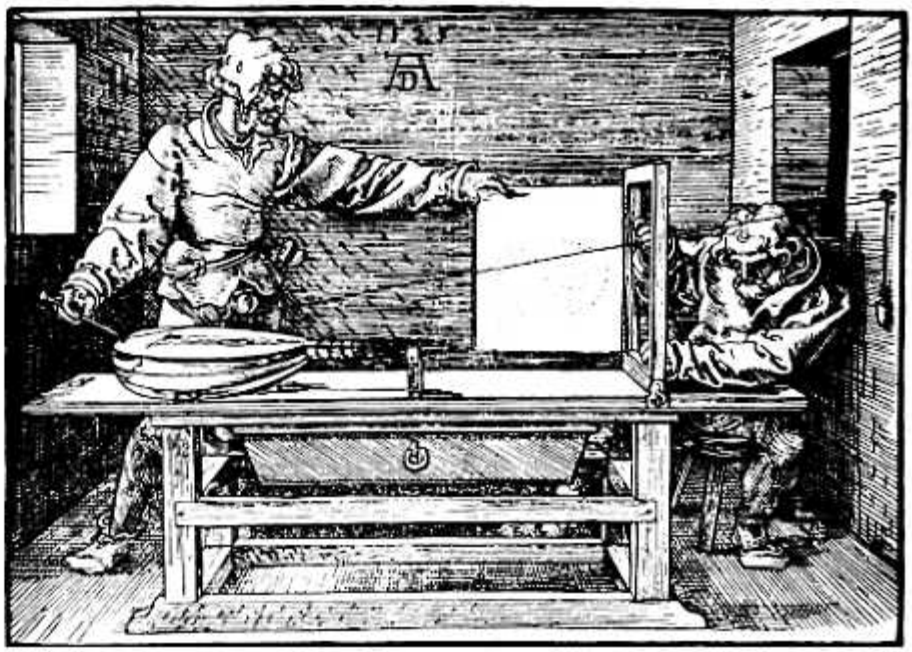
Human vision

Revealing the artist's touch

A.W. Snyder and H.B. Barlow

Is there a unifying conceptual framework for understanding human visual-information processing, one that explains the occurrence of illusions such as those of Ramachandran on page 163 of this issue[1]? Or is it better to regard our visual system as a mosaic of unrelated strategies, one for every special task[2]? An animal needs to make rapid decisions about what objects are where in its surroundings, but it has only a few neurons at its disposal: this strongly suggests that the brain should first simplify processing for detection and recognition of objects, and then report its findings with the utmost economy. We propose that these two principles provide a unifying interpretation of existing perceptual data and will enable us to place new results in a proper perspective.



Albrecht Dürer (1525). The use of object attributes to portray objects had to be learned by trial and error, and then taught to aspiring draughtsmen by the use of tricks and drawing aids.

Simplification of processing

Scenes presented to the eye are not an unlimited succession of surprises, but conform to certain patterns. Visual processing would become more rapid and efficient if the brain had expectations about what is to be seen, and it would be plausible for these expectations to become incorporated into perceptual mechanisms during the course of evolution. The structure and sequence of visual processing would then be determined by these expectations, which should reveal themselves as illusions in contrived or unnatural situations. Now natural scenes, as distinguished from the infinity of contrived scenes, are composed of discrete objects illuminated principally from one direction: it is such attributes of objects as they occur in the natural world, that should, if we are right, be structured into visual processing. Most of these attributes are in fact already well known to artists because they have had to master them to create the illusion of the three-dimensional world on a two-dimensional surface (see figure); relevant examples concern luminance gradients and colour.

Objects are often visible in our natural world by contrasting with the background, so that luminance borders are a prime attribute used to demark their outline. Provided the brain has been given definite clues that there is an object (for instance by the clearly visible curved corners in Fig. 4c of Ramachandran's paper, on page 165), the existence of a border all round the object will be assumed, and one will be seen where no border actually exists. A reasonable generalization (that objects have borders) leads to an illusion in this artificially contrived situation, but the generalization would be highly advantageous for rapid object detection in natural scenes. Various other illusions, such as the well-known Craik–Cornsweet illusion[3], show that borders alone can establish the contrast of objects. Finally, the idea[4] that the brain delays processing of internal regions until the border of the region is first established is supported by Ramachandran's Fig. 4c.

Consider next the artist's technique of shape from shading. This encapsulates the fact of our world that luminance gradients are a cue to the solid, three-dimensional percept. Indeed, Ramachandran shows[1] how the brain presupposes naturally occurring shading, with light from one direction. This assumption would lead to errors in a hypothetical world of diffuse or multiple light sources, but it simplifies the processing of natural scenes.

We could provide many other examples, such as perspective from texture gradients, but perhaps the most convincing economy of processing is demonstrated by colour vision. Isoluminance is rare in our natural world, partly because shading is an intrinsic property of three-dimensional objects. Thus, colour vision may have evolved for gaining attention and rapidly labelling objects that would be visible to an achromatic eye by virtue of their luminance borders. The brain could then simply associate coloured objects with their luminance borders, but some rather bizarre illusions are anticipated in unnatural situations. Stationary coloured objects can be seen to follow their associated (moving) luminant borders[5], even when the associated border is illusory[6].

Recognition of faces, and the perception of three-dimensionality, is extremely difficult in contrived situations where natural luminance gradients are replaced by colour gradients, even though the information content is similar. Furthermore, colour contributes little to motion[7,8] or to stereopsis[9,10]. Clearly, human colour processing is greatly simplified by assumptions about the natural world, but at the cost of erroneous and inadequate appearances in artificially contrived situations.

Economy of reporting

The brain might thus accelerate its formulation of the percept by incorporating expectations about object attributes into the structure and sequence of processing. The report of this percept might also be hastened by economy of reporting. It is the objects themselves that are important to an animal, not the object attributes processed by the brain to formulate the percept. Artists know that well-executed object attributes are not apparent even after careful inspection; the viewer sees the object itself instead. The more familiar of these attributes include shape from shading, perspective from gradients of texture, and size invariance with distance, but painters through the ages had to learn

their importance using trial and error[10]. Helmholtz[11] saw that "we are not in the habit of observing our sensations accurately, except as they are useful in enabling us to recognize external objects. On the contrary, we are wont to disregard all those parts of sensation that are of no importance so far as external objects are concerned". Thus, the brain reports only the object, suppressing information about the attributes used to find it. The reason, we suggest, is for economy of representation and reporting, an idea that may also be traced[12] back to the last century[13,14].

In summary, we think the brain has adopted two elementary simplifying principles, one for rapid processing of information and the other for rapid reporting. Many illusions are consistent with this interpretation, including those reported in this issue[1] by Ramachandran. It might henceforth be useful to view perception within this unifying perspective. □

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