roots of the ubiquitous pocket calculator or apprehensive about a future dominated increasingly by computers and electronic technocrats. It should be of particular interest to students of the history and sociology of 20th-century science, technology, and business and of technological revolutions in general.

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## Perceptual Constancy

**Stability and Constancy in Visual Perception.** Mechanisms and Processes. WILLIAM EPSTEIN, Ed. Wiley-Interscience, New York, 1977. xiv, 464 pp., illus. $22.50. Wiley Series in Behavior.

This book is organized around one of the major problems of classical perceptual research: how we perceive the objects and events of the visual world as stable despite the physical fact that the light at our eyes is continually changing.

The problem itself is not self-evident: Inasmuch as the surface colors (reflectances), sizes, shapes, and other attributes of objects are relatively stable, why should we be surprised that we perceive them so? To understand why, we must first distinguish the physical objects and their properties, which are distal stimuli, from the proximal patterns of stimulation the objects present to the sensory receptors in the eye. Under given viewing conditions, the size, shape, and luminance of the proximal stimulation that is provided by an object are determined by the object's size, shape, and reflectance. Change the object's distance, inclination to the line of sight, and illumination, and the size, shape, and luminance of its proximal stimulation change. In fact, subjects usually report that two objects appear equally light, say, or large when they are more alike in distal reflectance and size than in proximal stimulus pattern. On what information and by what processes, then, does the viewer identify the invariant object properties by means of varying stimulation?

The problem is methodologically attractive. Proximal and distal variables are usually relatively easy to vary independently and to measure precisely. And the theoretical issue is surely important. But the nature of the problem that is posed depends on our theory about how sensory information is extracted from the proximal stimulus pattern.

One approach to the problem, which yields the solution that is still favored by many or most psychologists, is that of Hermann von Helmholtz, who, as Johannes Müller's student, undertook the task of analyzing perception in terms of the unitary receptors or "specific nerve energies" available to each sensory modality. To Helmholtz the visual response to the proximal stimulus pattern was the independent activities of the photoreceptors in the retina and the set of individual sensations of color that accompany these. Our sensations of an object thus vary as the proximal stimulus varies, as it does with changing viewing conditions. We perceive stable object properties because we have learned to take into account the conditions of viewing, that is, whatever indications of distance and illumination are contained in the proximal stimulus pattern. "Taking into account" is a process similar in its general results to inference or syllogistic reasoning, except that it is unconscious. Most useful to this process are the sensory "experiments" on which each viewer bases his or her unconscious inductions: "By our movements we find out that it is the stationary form of the table in space which is the cause of the changing image in our eyes," Helmholtz wrote in *A Treatise on Physiological Optics*. Because distal object properties, not changing proximal stimulation, are important in our lives, we normally find it difficult to notice the changing sensations. We perceive instead those objects and events that would have been most likely under normal viewing conditions to produce the sensory impressions we have received.

Other approaches explain sensory response to proximal stimulation differently. If our receptor systems respond to the ratio of luminances between an object's image and its surround, and not to the absolute luminance of each, our responses would normally remain stable with the object's reflectance. Much of the reflectance constancy that our perceptions display could then be explained (as Ewald Hering and Ernst Mach proposed) without reference to processes such as "taking into account" or to the necessity of perceptual learning. It is easy to imagine neural circuitry that could accomplish such sensitivity to ratios of adjacent luminances, and some suitable circuitry has actually been found. The issue of perceptual constancy therefore intersects with the general nature-nurture issue, but it need not. Even if reflectance constancy is a result of learning, it might be a result of learning to attend to the ratio, not of unconscious inferences from mental structure.

More generally, we might hold with J. J. Gibson that by innate endowment, perceptual learning, or both, we extract the constant object attributes that provide a mathematical invariant that undergoes transformations in the changing proximal stimulation. According to this view, we respond directly to the invariant in the flux of changing proximal stimulation that specifies a table in space as we move around it and not through the working of any additional inference-like process. This is thus a holistic direct perception theory.

In the book under review, William Epstein provides thoughtful first and last chapters discussing the history and theoretical importance of the constancies and summing up contemporary findings along lines similar to those I have developed here. He concludes that both kinds of explanations are needed by the data and that both should be pursued.

Wayne Shebilske reviews recent research on the apparent stability of the apparent locations of objects in the field of view despite movements of the eye or head and concludes that neither a "taking into account" theory based on nonvisual (motoric) information about the direction and extent of movement nor one in which the stable distal stimulus is extracted as the invariant undergoing translation will explain the data. Sheldon Ebenholtz argues that something very much like Helmholtz's unconscious inference—what Ebenholtz calls an algorithm-processing approach—is manifested in the constancy of objects' apparent orientation despite changes in proximal orientation (such as is caused by tilting the viewer). Hiroshi Ono and James Comerford consider possible models to account for the perception of depth resulting from binocular disparity and the constancy of depth perception over different distances (the visual system must take viewing distance into account in assigning a definite depth to a particular disparity in the two eyes' views of an object) and find that there are too few data to decide between the models. Walter C. Gogel presents a great many data to support the familiar distinction between absolute ("that table is six feet away") and relative ("that table is nearer than that wall") sources of perceptual information and shows that they are often in conflict—a point difficult for a holistic direct perception theory to accommodate.

Although these five chapters are concerned more with describing fields of data than with what I believe to be the most important theoretical differences between the different classes of explanations of perceptual stability and constancy, it is clear that at the least they accept a Helmholtzian model as best fitting some of the component processes.

The remaining chapters deal with aspects of, but never directly address, what I consider to be the central question that now faces perception psychologists: What do we as scientists gain, and under what circumstances, by being able to say that X perceives Y? We had better mean more than that X says so. V. R. Carlson carefully analyzes how different instructions affect subjects' judgments and argues for example that "overconstancy" (judging a smaller, nearby object to be equal in size to a larger, remote object) occurs because experimental subjects correct their veridical perceptions to fit their biases about how things should look. I myself believe that remote objects look smaller than near ones just as often as they look equal to them. As I have suggested elsewhere, some tasks (for example, moving our eyes the right amount to disocclude a far object that is being hidden by a near one) require the former information, others require the latter. The point that we cannot simply take responses as percepts is well taken; the real question is what shall we take, and what do we gain by doing so?

According to Helmholtz's theory, the answer is clear: to say that we take our perceptions of distance into account in forming our perceptions of size is to say several powerful things. First, even though the perception of distance may be unreportable ("unconscious"), it is causal to the perception of size; the perception of size thus offers one way to give operational meaning to the perception of distance. Tadasu Oyama concludes from partial correlational analyses of subjects' judgments of such linked pairs of variables as size and distance or shape and slant that, although in most cases the two perceptual properties are independently determined by stimulus variables and no direct causal relation exists between them, in at least some cases—particularly when stimulus information is reduced—judgment of one perceptual property determines that of another.

Second, "taking into account" implies mental structure, constraints under which one percept implies another. Because normal viewing conditions provide external stimulus bases for both of a pair of percepts as direct responses, what is perceived when such information is missing, or is misleading, is of critical importance. Irwin Rock, writing "In defense of unconscious inference," reviews a variety of cases in which a negligible change in proximal stimulation leads to a change in perceived object property in accordance with the constraints that structure those properties in the physical world (for example, that, for a given a luminance, reflectance and illuminance are inversely related). Helmholtz assumed that such constraints are learned by experience with the structure of the physical world but had misgivings about the feasibility of doing the appropriate research with infants. R. H. Day and B. E. McKenzie survey the recent research on constancies in infants and conclude that infants do display shape constancy (respond to the same shape at different slants) by six to eight weeks of age but that early reports of size constancy have not been borne out.

Third, Helmholtz's theory requires that under "abnormal" viewing conditions the premises on which the inference-like processes are based will result in incorrect perceptions—not constancies, but illusions. Stanley Coren and Joan Girgus review a wide array of historical and current research on the traditional geometric illusions, with specific attention to the old proposal that such illusions occur because lines on paper are automatically treated (at least in pictorially educated cultures) as distance cues so that the consequent inference processes that would normally result in size constancy here yield misperceptions of size and shape. Although they conclude that many factors contribute to the illusions and that assumptions about inference cannot be applied in a general and straightforward fashion to either the illusions or to pictures, they find sufficient similarities between illusions and pictures to sustain a theoretical relation between constancies and illusions.

Most of these authors (and many others) attribute at least some perceptual phenomena to inference-like processes and therefore by implication to mental structure. Though I do not find most of their arguments compelling, they demonstrate that after a century of consideration the concept of mental structure remains both plausible and useful, in spite of having been repeatedly attacked. Other authors attempt to show that perception is direct. Gunnar Johansson reviews evidence that the viewer performs a vector analysis of the kinetic pattern of proximal stimulation and argues that such analysis recovers the invariant properties of the object being transformed in the moving viewer's retinal image and that the traditional problems of the constancies thus vanish when the appropriate metric of stimulus analysis is considered. This is surely more specific than the Helmholtz example of the invariant table undergoing transformation, but it does not obviate mental structure unless such responses are shown to be direct in some sense and unless all other major examples of inference-like process are similarly explained away. Identifying the neural structures underlying such responses would be the strongest argument for their directness; in his chapter Whitman Richards attempts to draw as many of the perceptual constancies as possible from the characteristics of complex and hypercomplex receptive fields. Even were our knowledge of such physiological mechanisms, and the "directness" of Johansson's phenomena, far better developed than it is at present, the mechanisms remain inapplicable to those examples of mental structure that cannot be attributed directly to stimulation because they exist only in the mind's eye. The changes that are reported to occur in the apparent relative size of the parts of models and pictures of "wire" objects when subjects perceive the distance relations to reverse, and the perception of objects that have been presented only piecemeal without any mathematical transformations to relate them to each other, stake at least some minimum claim for Helmholtzian mental structure.

If mental structure can be firmly established, exploring its origins, characteristics, and consequences is surely the most important task with which perceptual psychology can concern itself. Our tolerance of Escher-like "impossible objects" and the anomalies described in the Coren and Girgus chapter are sufficient to show that we cannot simply expect the premises of perceptual inference to reflect the structure of the physical world. The central issue of mental structure now deserves a more frontal assault. The present volume represents, I believe, the most that can be done to this point within the limits of traditional constancy research.

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## Magmatic Provinces

**Les Roches Volcaniques.** Pétrologie et Cadre Structural. M. GIROD and seven others. Doin, Paris, 1978. 240 pp., illus. Paper, 128 F.

The study of volcanic rocks used to be just a small branch of geology, consisting in observing and recording active volca-