Processes of the Central Eye

Foundations of Cyclopean Perception. BELA JULESZ. University of Chicago Press, Chicago, 1971. xiv, 406 pp., illus. $20.

It was about ten years ago that Bela Julesz published his first computer-generated random-dot stereograms. As he acknowledges in this book, there were precedents to his invention. Nevertheless, Julesz was among the first to recognize the potential usefulness of random-dot stereograms in the study of visual perception, and this book demonstrates that the resulting methodology has led to several substantive contributions. It is a beautiful book as well as an intriguing scientific document. The illustrations are superb and the typography and format are unusually attractive. The contents summarize an important segment of the research in visual perception that has gone on during the last decade.

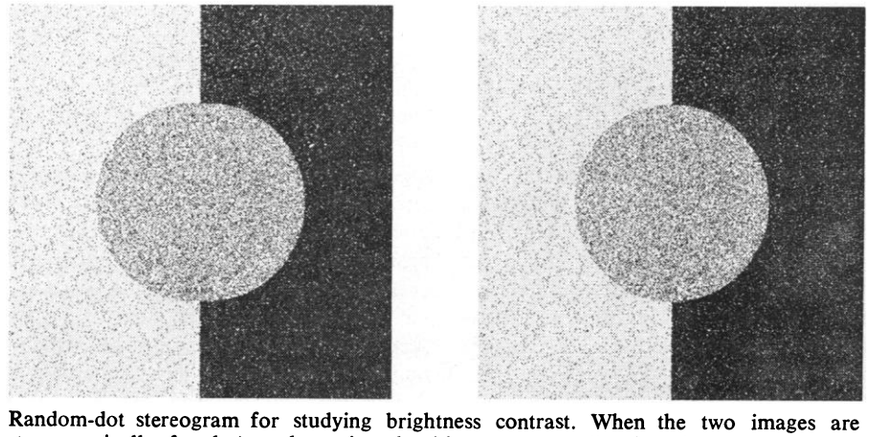
The book centers on two related themes. The first is binocular stereopsis per se. The second, the one that gives the book its title, stems from the idea that it is possible to bypass peripheral stages of the visual system and determine how later stages affect perceiving. The later stages are called "cyclopean retinae."

The basic Julesz pattern is a random array of dots. In the case of stereograms, one such array is presented to one eye and a similar pattern, differing only in that a central subset of the dots is shifted toward one side of the display, is presented to the other eye, so that corresponding clusters of dots are imaged on disparate retinal places. The resulting binocular disparity produces the perception of the shifted subset of dots in a separate plane of depth. The form of the segregated subset cannot be seen by either eye alone because the half-fields of the stereogram look like similar random textures. The contours of boundaries defining the binocular form may be thought of as being totally camouflaged by the random texture in the monocular views. Binocular parallax reveals these boundaries.

Taken by itself this result is not terribly surprising. Nevertheless, it is of interest that the low-frequency components of the binocular picture are extracted by the brain from the broad spectrum of spatial frequencies in the monocular views. The binocular forms must represent activity of the brain rather than peripheral processes located in the retina. Hence the random-dot stereogram may justly be described as a strong cyclopean stimulus.

In vision studies the term "cyclopean" was first used to refer to the fact that directions toward objects are perceived as originating at a point between the two eyes. In binocular vision one is not aware of the separate reception of an image in each eye. The image is experienced as single and as resting within some integrated field of view—the cyclopean eye. Julesz has extended the term to refer to stages of central processing of visual inputs. Moreover, to be truly cyclopean these stages must be capable of being selectively stimulated; they are not merely central. Julesz proposes that there are many cyclopean retinae. One of these is concerned with the generation of stereopsis; others may be responsible for form perception, movement perception, and so on. One of the problems to which this book is addressed is the discrimination of such stages from each other. For this purpose the author makes use of still other classes of cyclopean stimuli. He terms some of these stimuli "weakly cyclopean" because retinal factors may play some role in the generation of the resulting perception. An example of a weak stimulus is the form generated by means of very tiny breaks in dense arrays of vertical or horizontal lines. Another cyclopean stimulus is produced by rotating tiny needles about their centers; a subset of these many needles may be rotated at a velocity somewhat different from that of the others. Still another kind of stimulus is produced by the cinematograph. Here random-dot arrays are presented in sequence, subsets being moved to different positions from frame to frame of the film. This technique may be combined with stereoscopic methods so that pairs of motion-picture frames contain a systematic disparity and successive frames contain independent random sets of dots. These and many other techniques have been used to probe various topics in visual perception.

One of the topics probed by Julesz is the classical visual illusions. From time to time it has been suggested that some of the optical illusions are due to retinal factors. Julesz has confirmed the conclusion of others that such claims are not well founded. For example, random-dot stereograms are used to generate the Müller-Lyer illusion; the illusion persists despite the fact that the forms are not present on either retina alone. Similar results have led to the conclusion that many illusions are central in origin. Those illusions that are peripheral in origin are usually related to lateral inhibition, which we know occurs in the retina; but even in the case of illusions which are, prima facie, related to lateral inhibition there may be some central contribution. In modified Benussi figures, contrast phenomena may be enhanced by a cyclopean edge or contour. In the case of movement perception, Julesz has reached the tentative conclusion that stereopsis occurs prior to movement perception. However, he also speculates that there are movement analyzers at several different levels in the nervous system. In a lovely comparison of classical apparent movement of monocular lines with the apparent movement of stereoscopically presented stimuli he has found some striking qualitative differences. This suggests that higher-level movement detectors may be present



Random-dot stereogram for studying brightness contrast. When the two images are stereoscopically fused (as when viewed with eyes crossed), the disc appears to be divided vertically, the right-hand portion floating in a plane above and the left-hand portion in a plane below the plane of the square. The stereograms in Julesz's book are presented both in this form and as red-and-green anaglyphs, for which a color-filter viewing device is provided. [From *Foundations of Cyclopean Perception*]

and that they operate differently from simple movement detectors earlier in the visual system. Before one may accept this conclusion, however, I believe that we must be clearer about the role that may be played by convergent eye movements in the experiment, and also about the relation between movement perception and stereopsis in general.

Stereopsis per se is treated at some length in the book. Julesz surveys some of the older ideas about it. He persists in claiming to have discovered that familiarity plays no role in the process of stereopsis. It is my own feeling that this issue is a straw man; nobody has ever really believed that familiarity is an important factor in stereoscopic depth perception. Even if Julesz is right in this, it is the least important of his findings. To my mind, his most important discovery is that stereopsis is not based upon straightforward point-for-point fusion in the brain. If it were, then viewing his patterns would produce an ambiguous perception of depth. Every point would be able to fuse with all other points to produce "ghost" images at many different depth planes. But in fact, ghost points are just not visible. Classical fusion theories are deficient in that they cannot account for the absense of ghost images.

The avoidance of ghost images may involve some kind of pattern matching. However, the binocular fusion or matching of similar spatial contours, as implied by the work of Hubel and Weisel and of Barlow, Blakemore, and Pettigrew, is also unable to eliminate the problem of ghosts. Julesz therefore proposes a process of global stereopsis which depends upon the so-called "difference field." Difference fields may be created by point-for-point subtraction of one half-field from the other. When the half-fields are aligned so that the background dots are in register, the subtraction process will define the inner form. Similarly, shifting the half-fields by an amount equal to the disparity will also produce a difference field that contains the form. Julesz suggests that the visual system hunts for form in the various possible difference fields generated by shifting one half-field relative to the other. This form is what is perceived, and its depth from the fixation plane is given by the magnitude of shift necessary to get it.

Though some such process may be going on, it is difficult to see how it really differs from the basic idea of fusion of similar shapes or contours, except that fusion cannot be equated with summation. The difference field cannot account for the absence of ghost images in ordinary line stereograms. Also, there is no proposal as to what actually constitutes the hunting process entailed in finding stable depth. It is as though Julesz is simply indicating that the problem of ghosts exists and that a good theory will have to take it into account. Empty black boxes are proposed to recognize binocular forms, but how they do this is simply not known. It should be emphasized that Julesz is explicitly aware of most of these problems.

There is a second model of stereopsis in this book, the spring-loaded dipole model. This model was generated by consideration of what Julesz calls the "hysteresis phenomenon," which was discovered by Fender and Julesz when they viewed stabilized images of the two half-fields. The half-fields had to be brought within the classical Panum fusional areas before they could fuse and produce depth perception. However, once the images were fused they could be drawn far apart without loss of stereopsis. Fusion persisted even when the half-fields were separated by far more than the classical fusional limits.

The spring-loaded dipole model points to phenomena which classical fusional theory cannot explain. It shows that we must consider far more than the simple blending of matched inputs to account for stereopsis. It is disappointing, however, that Julesz does not speculate about the neural counterpart to the model. Moreover, the relation between this model and the difference-field model, if any, is not discussed.

I have a number of other criticisms of the book. First, it is not as well organized as I would like. Julesz pours challenging ideas all over its pages, but one is not quite sure how they hang together. Even ideas in the same chapter are sometimes not explicitly related to each other. Factors relevant to stereopsis are covered under the topic of cyclopean perception. In some respects the book resembles a catalog, of work accomplished and of hypotheses which remain to be tested. It lacks coherency.

The level of the discussion is sometimes inappropriate to its audience. Simple psychological ideas are sometimes explained at length while esoteric mathematics is referred to without much in the way of clarification for the nonmathematician. Yet the larger audience for this book will be from psychology.

This is a very personal book, most of the text being devoted to work accomplished by Julesz and his associates. An attempt is made to relate this impressive body of work to the work done by others, but it is only partially successful because Julesz does not always dwell upon the work of others sufficiently to make it clear.

Some very basic concepts are used in an ambiguous manner. The term "fusion," for example, is sometimes used as though it were synonymous with "depth perception," at other times as though it means phenomenal unification and the absence of rivalry. At still other times it could stand for a computation of depth which lies outside the awareness of the subject.

We must be careful about accepting the claim that the random-dot stereograms are devoid of all other cues to depth. One might suggest, for example, that the uniform texture of a half-field gives a Gibsonian cue that the array is flat. Mark Fineman has shown that this cue may be operating in conflict with disparity and that it could account in part for the long latency that sometimes precedes stereopsis. Though this does not vitiate the usefulness of the patterns, we must retain some reservations about the "purity" claimed for these stimuli.

Julesz is not always careful in documenting his findings. In most cases he has tried out his stimuli on large audiences. Moreover, he is a fine observer. But, since he does not follow the normal procedures in reporting psychological experiments, one is not always sure what weight to assign to a given result. In one case, for example, he reports that if one half-field of a line stereogram is enlarged relative to the other, stereopsis is more difficult to achieve than with a random-dot stereogram similarly treated. I, for one, have no trouble seeing depth in either of these stereograms. There are a few other stereograms which he reports to be more easily or less easily "fused." It would be well if such conclusions were buttressed by more than his testimony. In most cases, however, observation of the excellent stereograms confirms his conclusions.

On a more general level, this reviewer is somewhat disturbed by the concept of a cyclopean retina. Though it is proven that some illusions are not at-

tributable to peripheral factors, this does not establish that a unitary central stage has in fact been selectively stimulated. The Müller-Lyer illusion, for example, may be produced by tracing the outlines of the figures on the skin of an observer or by having an observer run his fingers over a raised surface shaped like the arrows of the illusion. This suggests that there are no discrete centers for different aspects of perception. Though Julesz does discuss the possibility of feedback from one stage to an earlier stage, he does not do much about it. Moreover, there is a tacit acceptance of the idea that the problems of perception are solved once one shows how a representation of the world may be formed within the nervous system. Julesz even refers to Hubel and Weisel's units as the "molecules of perception." This is reminiscent of the elementarism of the Structuralists. It leaves out the fact that anesthetized animals have responding sensory neurons but see nothing. Without the capacity for some kind of outflow there can be no perception. This is left out of consideration.

The extent to which Julesz is attracted to the idea that the study of perception involves the finding of representations of percepts at various levels in the brain is best illustrated by his notion about size constancy. He seems ready to accept the idea that if an observer reports that an object appears to grow larger there must be a concomitant enlargement of the representation of the object in the brain. Here he follows Richards in thinking in terms of a literal zooming process. It should be pointed out that many things can go on between a change in eye vergence or a change in perspective and the judgment of size. Gibson would give such effects a very different interpretation.

Despite all these reservations I must say that I found the book enthralling. It was in the 1860's that Helmholtz published the last volume of his *Treatise*. Apart from largely parametric studies, for the next hundred years little was done to deepen our understanding of binocular vision. At the end of that time we experienced a resurgence of interest in the field, and new insights resulted. Julesz's work was a major factor in creating this new trend. This book details his contributions and allows this reviewer to prophesy that we have not yet heard the last of him.

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A Central Concept in Anthropology

Three Styles in the Study of Kinship. J. A. BARNES. University of California Press, Berkeley, 1972. xxiv, 318 pp., illus. $8.75.

For the past century, since the publication of L. H. Morgan's *Systems of Consanguinity and Affinity of the Human Family* (1871), the study of kinship has been the central and distinctive feature of social anthropology, the arena in which distinguished careers have been forged on the basis of elaborate typologies, candidate laws, structural syntheses, and formal analytics. To borrow a well-worn analogy, the study of kinship is to social anthropology what the study of logic is to philosophy: the basic discipline of the subject.

In this volume J. A. Barnes analytically decomposes aspects of the work of three major kinship theorists, representing maximally contrasting theoretical positions (styles), in order to contribute to the development of "a truly cumulative theory of kinship." The theorists selected have all had a profound influence on the development of contemporary social anthropology. They are George Peter Murdock, Claude Lévi-Strauss, and Meyer Fortes. A chapter is devoted to the work of each, and the analysis is restricted to the study of kinship and the construction of models. The labels that identify the positions with which these anthropologists have become associated are "cross-cultural, statistically-based research," "French structuralism," and "orthodox British social anthropology," respectively. Their major works on the study of kinship were all published in 1949 and therefore (though there have been important subsequent developments) belong to the post-Malinowskian stage of development. Barnes's analysis, in his own assessment, belongs to the genre that is well exemplified by Abelard's *Sic et Non* (1122) and Parsons's *Structure of Social Action* (1937).

Although the three authors are ostensibly concerned with very similar substantive puzzles, they are, when considered pairwise, as different from one another as a whale is from a fish: they can be compared, to a limited extent, only because they swim in the same medium. This problem, which Barnes clearly recognizes, indicates that myths are far easier to take to pieces than they are to put together again.

Murdock's studies are associated with the development of the Human Relations Area Files as a basic laboratory resource, with large-scale comparative studies testing the statistical association of various cultural attributes, and with a synthetic form of interpretation that relies to a considerable extent upon an appeal to psychological processes associated with behavioral learning theory. Murdock's method of analysis, considered apart from his specific interpretations and definitions, is a ritual that has made it socially: quantitative, cross-cultural research is a thriving enterprise, the Human Relations Area Files are on deposit in many universities and research centers on both sides of the Atlantic, and there is considerable concern with derivative coding and sampling problems. The game has diffused to other fields of interpretation, such as social psychology, political science, and sociology.

Lévi-Strauss's structural approach, influenced by Roman Jakobson's distinctive-feature analysis of phonological systems (prosodic, tonality, and sonority features), regards the concrete realization of cultural forms—which Lévi-Strauss examines in minute detail—as a message whose meaning can be interpreted only in terms of an underlying code. The decoding process in this game merely constitutes the initial move: the basic conceptual innovation is the idea that codes from seemingly unrelated