The Role of Location Processing in the Perception of the Environment

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Abstract

Evolutionary considerations, anomalies in visual perception, and physiological and anatomical data provide support for the two-visual system hypothesis. In addition to the well-documented contour-processing system, there is also a largely independent location processing system that codes size, motion, number, and texture, as well as locus. This system appears to be flexible, parallel, high in capacity and unobtrusive in its operation. It is essentially analog, reflecting its suitability for the guidance of locomotion over a continuously varying terrain. A caution is raised concerning the excessive reliance on slides, on verbal report, and on concepts based solely on alphanumeric data.

The purpose of this paper is to provide some cautions and some guidelines for students of visual perception working at the psychology/environment interface. More specifically, this paper deals with recent developments that have led to a broadened conception of the processing of visual information, a critical link in how man perceives and thinks about his environment.

A pivotal concept in the modern psychology of perception is that of contour. Sharp edges, borders, and lines are prominent features of the visual world. Further, there is considerable evidence that single cells in the visual cortex respond to different kinds of contour information (Hubel & Wiesel, 1962). For example, some cells may be most sensitive to horizontal lines, some to lines at a 45° angle, and so on. Based on the pervasiveness of contour and the evidence for a physiological mechanism that codes contour into the activity of conveniently discrete elements, it is hardly surprising that some psychologists have concluded that the perception of contour is visual perception (e.g., cf. Thompson, 1969).

There are, however, a number of grounds for doubting this identity. First, there is the perspective provided by evolutionary considerations. Many of the aspects of the visual world that appear most essential to survival in a difficult and dangerous world seem quite far removed from contour. Secondly, there are a number of phenomena of visual perception that appear to be analog in nature, and are difficult to interpret along the essentially digital lines of the contour processing system.

The evolutionary perspective, although not widely held among psychologists, is not unfamiliar to students of psychology and environment (e.g., Shepard, 1966; Sommer, 1969; Hall, 1966; Carroll, 1970; Griffin, 1969). In considering the sorts of visual stimuli important to survival, it is useful to remember that at one point in man's prehistory his line was probably represented by a small, ground-dwelling undifferentiated mammal (Diamond & Hall, 1969). For such an animal, locus would seem to be of the greatest importance.

Motion, that is, a change in locus, appears to be another essential kind of stimulus information. Stimuli that move demand immediate attention. Besides motion in a plane, motion toward, called looming by Gibson (1969), and motion away appear critical. What one does with respect to a moving stimulus is, in turn, largely a function of size. Additional information a small animal might find helpful includes some rough indication of form and a notion of how many objects are present. Finally, texture, as the most general and pervasive guide to depth (Gibson, 1946), would be a useful addition to any animal concerned with making his way over uneven terrain.

As with the evolutionary considerations, several perceptual phenomena are also difficult to handle on the basis of contour alone. Figural aftereffects provide a striking example of a distortion of locus without a corresponding distortion of the figures in question. For example, after prolonged inspection of a pattern made of two adjacent squares and two distant squares, a pattern of four evenly spaced squares appears askew. The squares on the same side as the close together inspection squares appear far apart; likewise the squares on the side of the far apart inspection squares appear close together (Kohler & Wallach, 1944). The squares in this example tend to retain their crisp contours; the primary distortion is one of locus.
The strange behavior of solid figures in the fixed retinal image paradigm is another case in point. While portions of outline figures disappear in a discrete, all-or-none fashion, a solid figure appears to crumble (Heckenmueller, 1965). This clearly suggests that surface is coded differently from contour. (Surface here is assumed to be a location-like concept related to both size and texture.) Blurred images, that is, images with impoverished contours, likewise behave in an anomalous fashion (Fry & Robertson, 1935).

It thus appears that both adaptively crucial kinds of information and rather out-of-the-way perceptual anomalies point to the indispensability of the concept of location. Location is characterized by continuity; it is essentially an analog concept. Contour, by contrast, is largely digital; a given element may code the presence of a horizontal line while its neighbor may be concerned with some quite different feature.

These sorts of data suggest a fairly simple mechanism. Consider a two-dimensional array of elements in the brain corresponding point by point with the retina (the familiar topological representation of the gestalt visual brain). In such a system, locus might be coded by the peak of activity in the matrix of elements. (The point of maximal excitation concept is a familiar one in discussions of figural aftereffects and apparent movement, cf. Osgood, 1953.) Size would then be coded by the spread of activity about this point. Motion, of course, would be represented by a change in locus. Motion toward would be progressive increment in size, and motion away, a progressive diminution in size. Rough form and a crude notion of the number of objects present both appear to depend on the distribution of activity in the matrix. Unconnected loci could code number up to some limit (in humans the numbers of objects directly perceived, i.e., without counting, is approximately five -- providing no particular strain on the matrix interpretation). Rough form would arise from the configuration of connected loci, and from their sizes.

This proposed mechanism may at first glance appear simply to push the problem one step back, and in a sense this is true. The translation of the various patterns of excitation of matrix elements into reliable codes may in large part depend on learning. The hypothesized mechanisms for this learning are very general (that is, they are equally pertinent to the broad problems of pattern recognition) but their complexity puts them beyond the scope of this paper. In brief, a distance-biased random net composed of a large number of elements provides a structure in which any class of excitation patterns will tend to result in peak activity in a restricted set of elements "deeper" in the system (i.e., farther from the sensory interface). This convergence on a few elements that come to represent the class of events in question is discussed in greater detail in Kaplan (1970). Quite independent of the particular learning patterns involved, it appears that the location system might be considerably more flexible than the largely prewired contour system.

The conception of location processing discussed here was developed (some two years ago) solely on the basis of psychological data, and in fact flew in the face of most physiological data known to the author. There was, however, supportive physiological data in the literature at that time and more has been forthcoming (e.g., Schneider, 1969). This physiological research has centered around a primitive visual center, the superior colliculus. This tegmental visual system is the major processing region for vision in some animals and still functions in primates, including humans (Trevarthen, 1968, 1969). It is known to be related to the control of head and eye movements. It has rather undiscriminating receptive fields. That is, any element in this system is excited by a stimulus in the appropriate retinal region, quite independent of details of its form. [It should be pointed out that the elements in the tegmental system in cats are highly motion sensitive; the majority of them not only code motion but motion in a particular direction (Sterling & Wickelgren, 1969). Primate data, while similar in most respects, does not show this dependence on motion (Wurtz, 1970).] Thus, the available evidence is consistent with the simple matrix view of location processing.

Additional physiological evidence supports the further hypothesis that this system codes texture as well. For example, in cats the receptive fields vary in visual angle from 5° to 50° (Sprague et al., 1968). This means that different elements would be firing in the presence of fine as opposed to coarse texture.

Thus a convergence of evidence from a variety of sources supports the hypothesis of an at least partially independent location processing system. While there is a great deal yet to be learned about this system, a certain basic set of properties is beginning to emerge. This system appears to be uniquely important to those interested in how man experiences and builds maps of his visual world. It also appears to operate by rules quite different from those characteristic of the extensively studied contour-processing system.

The location processing system appears to be important in the directing of attention. Not only does it play a central role in the orientation of head and eyes, it also appears to have all the properties required for Neisser's (1967) pre-attentive process, that is, for the initial aspect of visual perception that precedes the construction or hypothesis-
testing stage. Neisser argues for a system that is rather crude, and highly parallel; the location system appears ideally suited to this role.

In addition to its attentive (or "pre-attentive") function, this system is intimately concerned with locomotion in space (Heid, 1970). Trevarthen (1968) refers to this component of visual information processing as "ambient vision." Certainly the wide visual angle characteristic of the system, its sensitivity to texture, and its capacity to process a continuous surface make it ideal for this function.

Since the system described here is necessarily a very primitive one, existing in comparatively simple animals, one is tempted to conjecture that it might operate largely outside the realm of consciousness, even in more complex organisms that have presumably developed some degree of consciousness. Indeed, as Trevarthen (1968) pointed out, traversing an uneven terrain appears in humans to be a reasonably efficient yet largely unconscious process. Thus it is possible that humans may have feelings about stimuli and may even be able to act on the basis of such stimulus information without being aware of taking in the information in question. In fact, the relative neglect of location processing by psychologists may be in part due to this very unobtrusiveness.

Another special feature of this system is its flexibility. The proposed matrix model depends heavily on learning for the establishment of coding patterns, and the available data are in line with this hypothesis. Heid (1970) points out that studies of relearning with distorting lenses strongly support the distinction between the two systems. Subjects learn to localize effectively under such conditions while still experiencing contour distortion, suggesting the superior flexibility of the location system as well as the validity of the distinction.

Further information about the unique properties of the location system comes from research with dot patterns. As Heid points out, dot patterns, in failing to define a contour, must be handled in terms of location. He finds illusions are perceived differently when defined by dots instead of contours, and further, that the act of pointing on the part of the subject yields data like that produced by dot stimuli (whether the stimuli are in fact contours or dots). A study requiring the location of dots in a visual array was carried out by Hill (1969). Since the traditional 72-channel capacity limitation found with alphanumeric visual stimuli has not been found with tactile patterns, Hill used dots to translate the tactile pattern into the visual mode. This visual task, like the tactile one, failed to show the channel capacity ceiling. Pachella (1970) indicates that in addition to confirming this result, he has found that the usual steady increase in performance as a function of increasing duration fails to hold for dot patterns.

The evidence, fragmentary as it is, seems to point clearly to a high capacity, highly parallel, highly flexible, and highly unobtrusive system. It appears also to be concerned, quite literally, with getting along in the world.

The existence of such a system has numerous implications, both theoretical and practical. We have become deeply concerned with how man experiences his environment; with his reactions to buildings and cities, to parks and to wilderness. In this research we cannot come to conclusions about the substituting of slides for space. The architect's model serves as a paradigm of the substitution of contour information for location information. Several studies have suggested that the planner's view of a city is markedly different from the experience of those who live there. Man may have strong preferences for certain spatial configurations. We must not assume that the individual's failure to mention some feature indicates that it plays no role. In matters of space intuitive and nonverbal reference patterns cannot be ignored.

There is a growing interest in the way man builds maps of the world in his head. In understanding this process we should consider cautiously information processing rules based on studies of alphanumeric visual material. It appears that not only the experience of space but also the process of locomotion itself are dependent upon a system which has received little study and which appears to operate by its own rules.

References

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