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SOME INFORMATIONAL ASPECTS OF VISUAL PERCEPTION

FRED ATTNEAVE

*Perceptual and Motor Skills Research Laboratory,
Human Resources Research Center* [1]

The ideas of information theory are at present stimulating many different areas of psychological inquiry. In providing techniques for quantifying situations which have hitherto been difficult or impossible to quantify, they suggest new and more precise ways of conceptualizing these situations (see Miller [12] for a general discussion and bibliography). Events ordered in time are particularly amenable to informational analysis; thus language sequences are being extensively studied, and other sequences, such as those of music, plainly invite research.

In this paper I shall indicate some of the ways in which the concepts and techniques of information theory may clarify our understanding of visual perception. When we begin to consider perception as an information-handling process, it quickly becomes clear that much of the information received by any higher organism is *redundant*. Sensory events are highly interdependent in both space and time: if we know at a given moment the states of a limited number of receptors (i.e., whether they are firing or not firing), we can make better-than-chance inferences with respect to the prior and subsequent states of these receptors, and also with respect to the present, prior, and subsequent states of other receptors. The preceding statement, taken in its broadest implications, is precisely equivalent to an assertion that the world as we know it is lawful. In the present discussion, however, we shall restrict our attention to special types of lawfulness which may exist in space at a fixed time, and which seem particularly relevant to processes of visual perception.

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THE NATURE OF REDUNDANCY IN VISUAL STIMULATION: A DEMONSTRATION

Consider the very simple situation presented in Fig. 1. With a modicum of effort, the reader may be able to see this as an ink bottle on the corner of a desk. Let us suppose that the background is a uniformly white wall, that the desk is a uniform brown, and that the bottle is completely black. The visual stimulation from these objects is highly redundant in the sense that portions of the field are highly predictable from other portions. In order to demonstrate this fact and its perceptual significance, we may employ a variant of the "guessing game" technique with which Shannon (17) has studied the

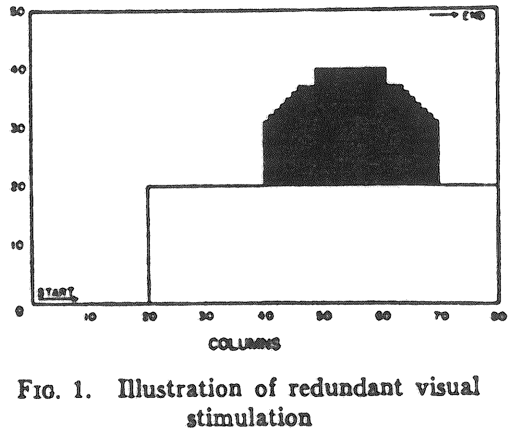

FIG. 1. Illustration of redundant visual stimulation

redundancy of printed English. We may divide the picture into arbitrarily small elements which we "transmit" to a subject (S) in a cumulative sequence, having him guess at the color of each successive element until he is correct. This method of analysis resembles the scanning process used in television and facsimile systems, and accomplishes the like purpose of transforming two spatial dimensions into a single sequence in time. We are in no way supposing or assuming, however, that perception normally involves any such scanning process. If the picture is divided into 50 rows and 80 columns, as indicated, our S will guess at each of 4,000 cells as many times as necessary to determine which of the three colors it has. If his error score is significantly less than chance $[2/3 \times 4{,}000 + 1/2(2/3 \times 4{,}000) = 4{,}000]$, it is evident that the picture is to some degree redundant. Actually, he may be expected to guess his way through Fig. 1 with only 15 or 20 errors. It is fairly apparent that the technique described, in its present form, is limited in applicability to simple and somewhat contrived situations. With suitable modification it may have general usefulness as a research tool, but it is introduced into the present paper for demonstrational purposes only.

Let us follow a hypothetical subject through this procedure in some detail, noting carefully the places where he is most likely to make errors, since these are the places in which information is concentrated. To begin, we give him an 80×50 sheet of graph paper, telling him that he is to guess whether each cell is white, black, or brown, starting in the lower left corner and proceeding across the first row, then across the second, and so on to the last cell in the upper right corner. Whenever he makes an error, he is allowed to guess a second and, if necessary, a third time until he is correct. He keeps a record of the cells he has been over by filling in black and brown ones with pencil marks of appropriate color, leaving white ones blank.

After a few errors at the beginning of the first row, he will discover that the next cell is "always" white, and predict accordingly. This prediction will be correct as far as Column 20, but on 21 it will be wrong. After a few more errors he will learn that "brown" is his best prediction, as in fact it is to the end of the row. Chances are good that the subject will assume the second row to be exactly like the first, in which case he will guess it with no errors; otherwise he may make an error or two at the beginning, or at the edge of the "table," as before. He is almost certain to be entirely correct on Row 3, and on subsequent rows through 20. On Row 21, however, it is equally certain that he will erroneously predict a transition from white to brown on Column 21, where the *corner* of the table is passed.

Our subject's behavior to this point demonstrates two principles which may be discussed before we follow him through the remainder of his predictions. It is evident that redundant visual stimulation results from either (a) an area of homogeneous color ("color" is used in the broad sense here, and includes brightness), or (b) a contour of homogeneous direction or slope. In other words, information is concentrated along contours (i.e., regions where color changes abruptly),[2] and is further concentrated at those points on a contour at which its direction changes most rapidly (i.e., at angles or peaks of curvature).

[2] Our "scanning" procedure introduces a certain artifact here, in that a particular subject will make errors at a linear contour only the first few times he crosses it. It is fairly obvious that if the starting point of the sequence and the direction of scan were varied randomly over a large number of subjects, summated errors would be distributed evenly along such a straight contour.

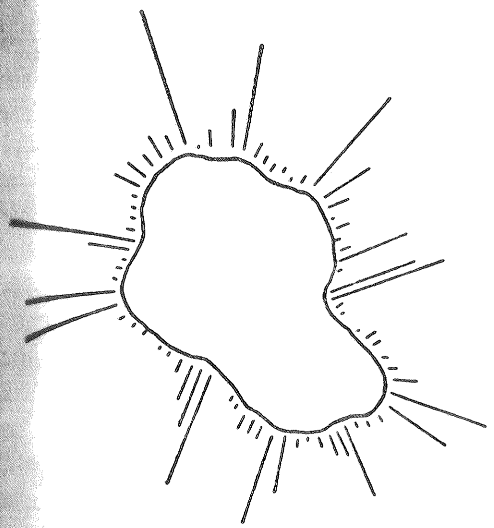

FIG. 2. Subjects attempted to approximate the closed figure shown above with a pattern of 10 dots. Radiating bars indicate the relative frequency with which various portions of the outline were represented by dots chosen.

Evidence from other and entirely different situations supports both of these inferences. The concentration of information in contours is illustrated by the remarkably similar appearance of objects alike in contour and different otherwise. The "same" triangle, for example, may be either white on black or green on white. Even more impressive is the familiar fact that an artist's sketch, in which lines are substituted for sharp color gradients, may constitute a readily identifiable representation of a person or thing.

An experiment relevant to the second principle, i.e., that information is further concentrated at points where a contour changes direction most rapidly, may be summarized briefly.[8] Eighty *Ss* were instructed to draw, for each of 16 outline shapes, a pattern of 10 dots which would resemble the shape as closely as possible, and then to indicate on the original outline the exact places which the dots represented. A good sample of the results is shown in Fig. 2: radial bars indicate the relative frequency with which dots were placed on each of the segments into which the contour was divided for scoring purposes. It is clear that *Ss* show a great deal of agreement in their abstractions of points best representing the shape, and most of these points are taken from regions where the contour is most different from a straight line. This conclusion is verified by detailed comparisons of dot frequencies with measured curvatures on both the figure shown and others.

Common objects may be represented with great economy, and fairly striking fidelity, by copying the points at which their contours change direction maximally, and then connecting these points appropriately with a straightedge. Figure 3 was drawn by applying this technique, as mechanically as possible, to a real sleeping cat. The informational content of a drawing like this may be considered to consist of two components: one describing the positions of the points, the other indicating which points are connected with which others. The first of these components will almost always contain more information than the second, but its exact share will depend upon the precision with which positions are designated, and will further vary from object to object.

Let us now return to the hypothetical subject whom we left between the corner

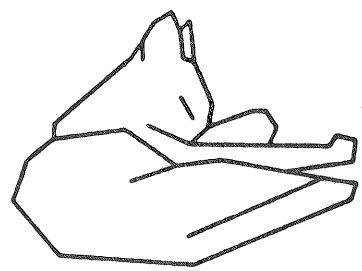

FIG. 3. Drawing made by abstracting 38 points of maximum curvature from the contours of a sleeping cat, and connecting these points appropriately with a straightedge.

[8] This study has been previously published only in the form of a mimeographed note: "The Relative Importance of Parts of a Contour," Research Note P&MS 51-8, Human Resources Research Center, November 1951.

of the table and the ink bottle in Fig. 1. His errors will follow the principles we have just been discussing until he reaches the serrated shoulders of the bottle. (A straight 45° line would be represented in this way because of the grain of the coordinate system, but we shall consider that the bottle is actually serrated, as it is from the subject's point of view.) On the left shoulder there are 13 right angles, but these angles contain considerably less than 13 times the information of an angle in isolation like the corner of the table. This is true because they fall into a pattern which is repetitive, or redundant in the everyday sense of the term. They will cease to evoke errors as soon as *S* perceives their regularity and extrapolates it. This extrapolation, precisely like *S*'s previous extrapolations of color and slope, will have validity only over a limited range and will itself lead to error on Row 38, Column 48.

At about the same time that he discovers the regularity of the stair-step pattern (or perhaps a little before), our *S* will also perceive that the ink bottle is symmetrical, i.e., that the right contour is predictable from the left one by means of a simple reversal. As a result he is very unlikely to make any further errors on the right side above Row 32 or 33. Symmetry, then, constitutes another form of redundancy.[4]

It should be fairly evident by now that many of the gestalt principles of perceptual organization pertain essentially to information distribution. The *good gestalt* is a figure with some high degree of internal redundancy. That the grouping laws of *similarity, good continuation*, and *common fate* all refer to conditions which reduce uncertainty is clear enough after the preceding discussion, and we shall presently see that *proximity* may be conceptualized in a like manner. It is not surprising that the perceptual machinery should "group" those portions of its input which share the same information: any system handling redundant information in an efficient manner would necessarily do something of the sort. Musatti (20) came very close to the present point when he suggested that a single principle of *homogeneity* might subsume Wertheimer's laws as special cases. All of our hypothetical *S*'s extrapolations have involved some variety of homogeneity (or invariance), either of color, of slope, or of pattern.

The kinds of extrapolation that have been discussed certainly do not exhaust the repertory of the human observer. For example, if the brightness of a surface were changed at a constant rate along some spatial extent, an observer could probably extrapolate this change with a fair degree of accuracy (given an appropriate response medium, such as choosing from a set of Munsell color patches). Likewise, we may reasonably suppose that a contour, the direction of which changes at a constant rate (i.e., the arc of a circle), could be extrapolated. Any sort of physical invariance whatsoever constitutes a source of redundancy for an organism capable of abstracting the invariance and utilizing it appropriately, but we actually know very little about the limits of the human perceptual machinery with respect to such abilities. A group of psychophysi-

[4] The reader may be comforted to know that six subjects have actually been run on the task described. Their errors, which ranged in number from 13 to 26, were distributed as suggested above, with a single interesting exception: 4 of the 6 *S*s assumed on Row 1 that the brown area would be located symmetrically within the field, and guessed "white" on Column 61. By the use of Shannon's formulas (17) it was estimated that the field contains between 34 (lower limit) and 156 (upper limit) bits of information, in contrast to a possible maximum of 6,340 bits. The redundancy is thus calculated to be between 97.5 and 99.5 per cent.

cal studies determining the accuracy with which observers are able to extrapolate certain discrete and continuous functions of varying complexity must be carried out before we can usefully discuss any but the simplest cases.[8]

A troublesome question arises in this connection: where does perception leave off and inductive reasoning begin? The abstraction of simple homogeneities from a visual field does not appear to be different, in its formal aspects, from the induction of a highly general scientific law from a mass of experimental data. Certain subjective differences are obvious enough: thus reasoning seems to involve conscious effort, whereas perception seems to involve a set of processes whereby information is *predigested* before it ever reaches awareness. When extrapolations are required of a subject in an experimental situation, however, it is difficult or impossible for the experimenter to be certain whether the subject is responding on an "intuitive" or a "deliberative" basis. I do not know any general solution to this problem, and can only suggest that a limited control may be exercised by way of the establishment of a desired set in the subject.

[8] There is, however, a great deal more that can be said about the simplest cases. Vernier acuity demonstrates that, under optimal conditions, error of extrapolation may be less than the "minimum separable." It has been found by Salomon (16) that the error made in "aiming" a line at a point some constant distance from its end is a decreasing, negatively accelerated function of the line's length. This may be taken to mean that increasing the length of a line adds information about its extension, but at a decreasing rate, somewhat as increasing the length of a passage of English text adds decreasing increments of information about the next letter (13, 17). Dr. Karl Zener, under whose direction the Salomon study was done, is at present conducting a program of related psychophysical experiments which may answer some of the questions raised above.

THE ABSTRACTION OF STATISTICAL PARAMETERS

Although Fig. 1 presents a situation much simpler, or more redundant, than the visual situations which ordinarily confront us, the reader need merely look around the room in which he is sitting to find that the principles illustrated apply to the real world. Further, it may be argued on neurological grounds that the human brain could not possibly utilize all the information provided by states of stimulation which were not highly redundant. According to Polyak's (14) estimate, the retina contains not less than four million cones. At any given instant each of these cones may be in either of two states: firing or not firing. Thus the retina as a whole might be in any one of about $2^{4,000,000}$ or $10^{1,200,000}$ states, each representing a different configuration of visual stimulation. Now, if by some unspecified mechanism each of these states were to evoke a different unitary response, and if a unitary response consists merely of the firing of a single unique neuron, then $10^{1,200,000}$ of such response-neurons would be required. The fantastic magnitude of this figure becomes somewhat apparent when one calculates that only about 10^{54} neurons could be packed into a cubic light year. The fact that the number of *patterns* of response-neurons might plausibly equal the number of retinal configurations simplifies matters only if there are certain one-to-one connections between cones and response-neurons, in which case the response is to some degree merely a copy of the stimulus.

We may nevertheless ask: how *would* an observer respond to a situation in which the retinal receptors were stimulated quite independently of one another? This situation would be in practice very difficult to achieve (even more difficult than its diametric opposite, the

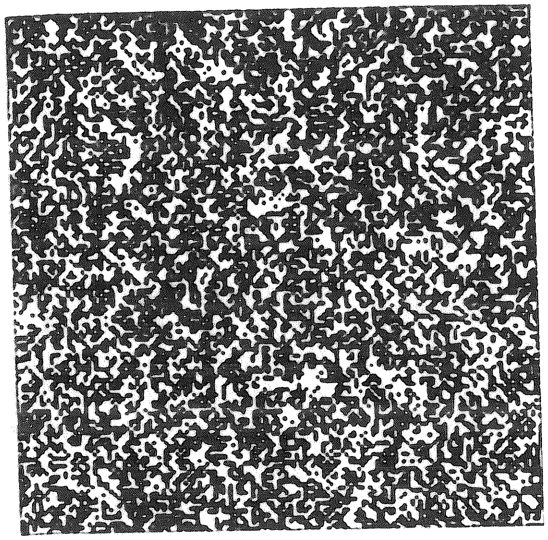

FIG. 4. A "random field" consisting of 19,600 cells. The state of each cell (black vs. white) was determined independently with a *p* of .50.

Ganzfeld), particularly if we demanded that the stimulation at a given moment (which might be supposed to have a duration of about 100 msec. [see Attneave and McReynolds, 1]) be entirely independent of the stimulation at any other moment. In an effort to get some notion of what such a random field would be like, Fig. 4 was constructed. Each of the $140^2 = 19{,}600$ small cells of the figure was either filled or not filled according to the value of a number obtained from a conversion of Snedecor's (18) table of random numbers from decimal to binary.[6] If the figure is viewed from a distance such that the angle subtended by a cell is of the order of the "minimum separable" (about 1′), it illustrates roughly how a small portion of the random field suggested abov might look at some particular instan Perhaps the most striking thing abou the figure is the subjective impressio of *homogeneity* that it gives: the le half of the figure seems, at least in general way, very much like the righ half. This is remarkable because w have previously associated homogeneit with redundancy, and Fig. 4 was coı structed to be completely nonredundan Now, in psychological terms, it is fairl clear that the characteristic with respe to which the figure appears homogen ous is what Gibson (6) would call i *texture*. In physical terms, two invar ant factors may be specified: (*a*) tl probability (.50) that any cell will l black rather than white, and (*b*) tl size of cells. Both of these factors prol ably contribute to perceived textur which is undoubtedly a multidimeı sional variable, though the latter ma be somewhat the more important. the figure is viewed from a sufficieı distance, these two parameters becoı identifiable with (*a*) the central ten ency, and (*b*) the dispersion, of a coı tinuous brightness distribution in tw dimensions.

It appears, then, that when some po tion of the visual field contains a quaı tity of information grossly in excess the observer's perceptual capacity, l treats those components of informatic which do not have redundant represeı tation somewhat as a statistician trea "error variance," averaging out partic lars and abstracting certain statistic homogeneities. Such an averaging pro ess was involved in drawing the cat f Fig. 3. It was said earlier that tl points of the drawing corresponded places of maximum curvature on tl contour of the cat, but this was n strictly correct; if the principle ha been followed rigidly, it would ha been necessary to represent the ends individual hairs by points. In observ

[6] This laborious task was carried out by Airmen 1/C W. H. Price and E. F. Chiburis. Unfortunately, a slight distortion of the relative sizes of black and white cells was introduced in the photographic copying process. The figure was constructed not only for demonstration purposes, but also to serve as a source of random patterns for experimental use. It may also be used wherever a table of random binary numbers is needed, facilitating, for example, the selection of random "draws" from a binomial distribution.

ing a cat, however, one does not ordinarily perceive its hairs as individual entities; instead one perceives that the cat is *furry*. Furriness is a kind of texture; the statistical parameters which characterize it presumably involve averages of shape and direction, as well as size, of elements. The perceived *contour* of a cat (e.g., the contour from which the points of Fig. 3 were taken) is the resultant of an orthogonal averaging process in which texture is eliminated or smoothed out almost entirely, somewhat as if a photograph of the object were blurred and then printed on high-contrast paper (cf. Rashevsky, 15, and Culbertson, 5).

The sense in which a surface of a particular texture may be said to provide redundant stimulation has perhaps been adequately indicated. This sort of redundancy might be demonstrated by the guessing-game technique, with a suitable modification in the level of prediction required, i.e., by increasing the unit area to be predicted and requiring the subject to select from a multidimensional array of samples the texture (i.e., the statistical parameters) which he believes the next unit will have. In view of Gibson's (6) convincing argument that a physical edge, or contour, is as likely to be represented in vision by an abrupt texture change as by an abrupt color change, I have considered it important to show how texture may be substituted for color without materially altering the principles derived from Fig. 1.

PERCEPTION AS ECONOMICAL DESCRIPTION

It is sometimes said that the objective of science is to describe nature economically. We have reason to believe, however, that some such process of parsimonious description has its beginnings on a fairly naive perceptual level, in scientists and their fellow organisms alike; thus the difficulty, mentioned earlier, of distinguishing between perception and inductive reasoning. It appears likely that a major function of the perceptual machinery is to strip away some of the redundancy of stimulation, to describe or encode incoming information in a form more economical than that in which it impinges on the receptors.

If this point of view is sound, we should be able to generate plausible hypotheses as to the nature of specific perceptual processes by considering rational operations which one might deliberately employ to reduce redundancy. The approach suggested, as it applies to the perception of a static visual field, is equivalent to that of a communications engineer who wishes to design a system for transmitting pictures of real things over a practically noise-free channel with the utmost economy of channel time and band width, but in a manner designed to meet standards such as human observers are likely to have. Some of the reduction principles which he might usefully employ in such a system are listed below. It will be found that these principles serve to summarize and integrate ideas which have been developed somewhat informally in the foregoing sections, as well as to introduce new considerations. The principles may be grouped according to the forms of redundancy with which they are concerned: thus 1–4 deal with varieties of continuous regularity; 5 and 6 with discontinuous regularity, or recurrence; 7–9 with proximity; and 10 with situations involving interaction.

1. An area of homogeneous color may be described by specifying the color and the boundaries of the area over which it is homogeneous. (It is assumed that limits of error tolerance on relevant dimensions have been agreed upon, e.g., that there is some definite number of

colors from which the receiving mechanism may be directed to choose.)

2. Likewise, an area of homogeneous texture may be described by specifying the statistical parameters which characterize the texture and the boundaries of the area over which these parameters are relatively invariant. Thus, if Fig. 4 represented a part of the upholstery of a sofa, it would probably be satisfactory simply to instruct the receiving mechanism to reproduce the texture by filling in cells of a certain size from any table of random numbers. It is true that this process would result in the complete loss of 19,600 bits of information; the essential point is that we are dealing here with a class of stimuli from which such a huge information loss is perceptually tolerable.

3. An area over which either color or texture varies according to some regular function may be described by specifying the function and the boundaries of the area over which it obtains (cf. Gibson's [6] *texture gradient*). This principle actually implies both 1 and 2 as special cases.

4. Likewise, if some segment of an area boundary (i.e., contour) either maintains a constant direction or varies according to some other regular function, it may be described by specifying the function and the loci of its limiting points. Figure 3 illustrates a special case of this principle.

5. If two or more identical stimulus patterns (these might be either successive portions of a contour, or separate and discrete objects) appear at different places in the same field, all may be described by describing one and specifying the positions of the others and the fact that they are identical (cf. *similarity* as a grouping law).

6. If two or more patterns are similar but not identical, it may be economical to proceed as in 5, in addition specifying either (a) how subsequent patterns differ from the first, or else (b) how each pattern differs from some skeleton pattern which includes the communalities of the group (cf. the "schema-with-correction" idea discussed by Woodworth [20]; also Hebb's [7] treatment of perceptual schemata).

7. When the spatial loci of a number of points are to be described in some arbitrary order, and the points are arranged in clusters or proximity groups (as in Fig. 5), it may be economical to describe the points of each group with respect to some local origin (O' or O''), transmitting as a separate component the positions of the local origins with respect either to each other or to some arbitrary origin, whichever is required. Since the points occupy a smaller range of alternative coordinates on the local axes than on arbitrary axes, less information is required for their specification. If the amount of information thus saved is greater than the amount needed to specify the positions of the local origins, a net saving will result. What is redundant in the present case is the *approximate location* of points in a cluster: this component is isolated out when a local origin is described (cf. the con-

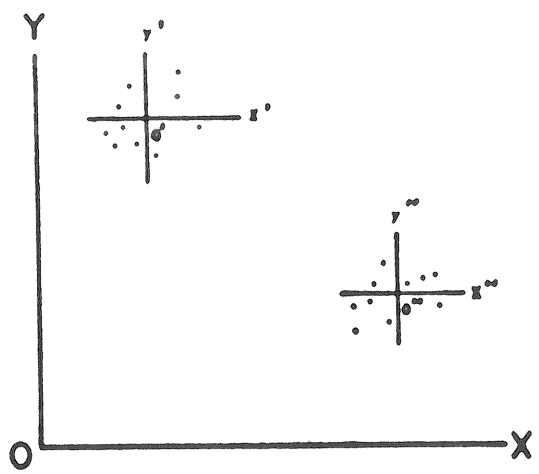

FIG. 5. A functional aspect of proximity-grouping is illustrated. The loci of clustered points may be described with choices from a smaller set of numbers if local origins are used.

cepts of "within" and "between" variance). The local origin principle may also be used in conjunction with some regular scanning procedure if the order in which the points are to be specified is not predetermined (but see also 9, below). The relevance of these considerations to *proximity* as a perceptual grouping law is evident.

8. The preceding principle may be generalized to apply to dimensions other than spatial ones; e.g., brightness, coarseness of texture, etc. A "local origin" on such a continuum would appear to have essentially the characteristics of Helson's (8) *adaptation-level*, in terms of which constancy phenomena and a variety of other psychophysical findings may be accounted for. This generalized principle is closely similar to 6 above, the chief difference being that 6 is applicable to combinations of discrete variables, or to situations of ambiguous dimensional organization.

9. If the loci of a number of points are to be described, and the order in which they are taken is immaterial, they may be arranged in a sequence such that the distances between adjacent points are minimized, and transmitted with each point serving as origin for the one following it. This procedure will result in some saving if the points are clustered, as in Fig. 5, but it is most clearly applicable when the points are "strung-out" in some obvious sequence. In the latter case, a further economy may be achieved by the use of special coordinates such as distance from a line passing through the two preceding points (or from an arc through the three preceding points, etc.; cf. 4 above).

10. Certain areas and objects may be described in a relatively simple way, by procedures of the sort suggested above, if they are first subjected to some systematic distortion or transformation. Consider the case of a complex, symmetrical, two-dimensional pattern viewed from an angle such that its retinal or photographic image is not symmetrical. It will be economical to transmit a description of the pattern as if it were in the frontal plane, and thus symmetrical (eliminating the redundancy of symmetry by means of 6*a*), together with a description of the transformation which relates the frontal aspect described to the oblique aspect in which the pattern is viewed (cf. Gibson's [6] discussion of perspective transformations; also the "Thompsonian coordinates" of D'Arcy Thompson [19]). Koffka (10) and other gestalt psychologists have held that many objects have some "preferred" aspect, and that this aspect has the characteristics of a "good gestalt." The present principle supports this view on functional grounds, since the perceptual transformation of a figure to an aspect in which similarities among parts are maximized may be interpreted as the initial step in an efficient information-digesting process. It should be clearly recognized, however, that an over-all economy is achieved only if the amount of information required to describe the transformation is less than the amount of information saved by virtue of the transformation; thus a transformation must be relatively simple to be considered useful, at least by the present criterion.

Let me indicate briefly how these considerations may be integrated with others of a more general nature. Interdependencies among sensory events may exist either in space or in time, or they may cut across both space and time. In studying the redundancy of spoken English (11), for example, one is dealing with interdependencies which may be considered purely temporal. The present discussion has been restricted, quite arbitrarily, to relationships in space: to forms of redundancy and information-distribution which may obtain in the visual field at a particular instant, and which a computer of conceivable complexity might evaluate from a photograph. The extension of the visual field in time, which I propose to discuss in a subsequent paper, introduces new varieties of redundancy involving the temporal continuation or recurrence of spatial configurations which may be nonredundant at any instant considered in isolation. Any individual learns a great deal, over his life span, about what-goes-with-what. Thus, if an ear is disclosed in a situation like that illustrated by Fig. 1, the observer can predict that a mouth, nose, eyes, etc. are also present, and approximately where they are. This sort of redundancy is spatiotemporal in its basis; predictions are not possible merely on the basis of the present visual field, but depend also upon previous fields which have contained faces. Principle 6 above suggests the approach to economical description which might be extended to such cases. Further, as Brunswik (2, 3, 4) has pointed out in some detail, ecological principles of very broad generality may be derived from experience.[7] For example, the frequency with which an observer has encountered symmetrical objects in his past may certainly affect the point at which, in predicting successive cells of Fig. 1, he "assumes" that the ink bottle is symmetrical. Likewise in terms of economical encoding: each of the varieties of spatial redundancy suggested above will itself occur with some determinate frequency over any given set of fields (e.g., the set of pictures which a computer-transmitter might have been required to handle over some period of past operation), and a knowledge of this and related frequencies may be used in determining the optimal assignments of actual code symbols. As a result of factors such as these, spatial and spatiotemporal redundancy (or entropy) are difficult to separate empirically, but the distinction remains a conceptually convenient one.

The foregoing reduction principles make no pretense to exhaustiveness. It should be emphasized that there are as many kinds of redundancy in the visual field as there are kinds of regularity or lawfulness; an attempt to consider them all would be somewhat presumptuous on one hand, and almost certainly irrelevant to perceptual processes on the other. It may further be admitted that the principles which have been given are themselves highly redundant in the sense that they could be stated much more economically on a higher level of abstraction. This logical redundancy is not inadvertent, however: if one were faced with the engineering problem suggested earlier, he would undoubtedly find it necessary to break the problem down in some manner such as the foregoing, and to design a multiplicity of mechanisms to perform operations of the sort indicated (some principles, e.g., 6, would require further breakdown for this purpose). Likewise, the principles are frankly intended to suggest operations which the perceptual machinery may actually perform, and accordingly the types of measurement which are likely to prove appropriate in the quantitative psychophysical study of complex perceptual processes.

[7] Brunswik (2), Hebb (7), and the Ames group at Princeton (9) have advanced views concerning the role of experience in perception which have much in common with one another and with my own position in the matter. It appears to me, however, that they have in general tended to underestimate (as the gestalt psychologists have somewhat overestimated) the importance of lawful relationships which may exist within the static and isolated visual field.

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