Photo 17. Aspect from the openning of the Third International Congress of Cybernetics and General Systems

Perception and topology

S3.4

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After considering the methodology of the relation between perception and topology the author discusses the concept of perception with emphasis on the externoceptive variety.
A possible scheme for the construction of some perceptual mosaics is proposed. The paper concludes with a reference to interoceptive perception.

1. METHODOLOGICAL INTRODUCTION

In spite of the increasing number and of the quality of papers devoted to neurology and sensorial physiology, one would hardly say that we understand how for instance visual images are produced, or how the consciousness we have of these images is established.

Our knowledge of the nervous systems are too often local, or on the contrary very general. The functional role of the elements which are observed or studied, frequently escapes our understanding. However, mathematical models have been built which sometimes present some interest. Yet, we have to recognize that, in general, our knowledge and our understanding of the biochemical and biological substrates are too fragmentary to allow us to built up fruitful models. In the first volume of the *Handbook of Sensory Physiology*, R. Jung has defended this thesis with strength and clarity, and it would be appropriate for us to subscribe to it.

Over-axiomatic and over-precise biological models often quickly lose their interest in the light of new discoveries for neurophysiologists. Of course, it would be rather unwise to condemn outright such attemps to set up rigorous models. In the actual state of our neuro-physiological knowledge, it would also be unreasonable to cast doubt on even the vaguest models or on even simple outlines of models, since in time, with the progress of experimental knowledge, such models will inevitably become more precise and so more rigorous.

We have to deal with the phenomenon of the living world, whose essential characteristic is plasticity. Thus the models to consider must be, above all, models of a dynamic nature, whether they be models where the geometrico-differential basis is preponderant (dynamical systems, theory of catastrophies) or models with hydrodynamical settlement. We intend simply, in this short paper, to give a survey of some examples of the use of geometrical concepts underlying these dynamical models* in perception theory.

2. NOTION OF PERCEPTION

The rather vague concept of perception cannot be embodied into a simple and short definition. Indeed, to encompass this definition, philosophers have often made great efforts. We obtain more clarity by taking into account the functional role of perception.

* Control and Topology, appeared in Modern Trends in Cybernetics and Systems, vol. II, Editura Tehnica, Bucharest, 1977

What is usually meant under this term is a set of various activities and organizations whose true purpose is to contribute to the maintenance, and to the survival of the biological being in its active state. To reach this goal, the individual and social-biological machine needs energy. Thus the living being attempts to develop a whole set of mechanisms to localize, grasp, transform and keep this energy.

The localization may be practically immediate. In this case, we shall, in general, say that this form of perception is "turned towards the exterior" or is "externoceptive". The corresponding perceptive activity calls, in the first instance, for the work of the classical sensorial faculties.

Opposite to this mode of perception, is a second type of perception, the "interno-verty" perception. When the localization of energy cannot be done all at once, the mind is led to conceive a whole set of rapprochements, of comparisons, of analogies and of consequences that have to be grasped, and to be brought up to the conscious level. The goal of this mental work is to simulate the situation of the subject and its environmment, and to determine the various behaviours which must follow in order to set the subject up in an optimal energetic position.

Though we deal with mental or sensory perception, we should not forget that, etymologically, to perceive means not merely to grasp by means of the senses, but to pick among, which implies to experiences, to choose and to grasp.

3. ON THE EXTERNOCEPTIVE PERCEPTION

3.1. Phylogenetic study of forms. Any energetic form has a past. It has gone through an evolution. It has obeyed, in some way, the biological rules of differentiation and complexification. Grosso modo, these forms can be classified according the following scheme:

Energy

physical

chemical

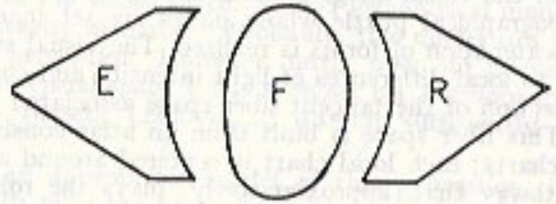
biochemical

vegetable   animal

One should notice the reversible character of this affiliation which might be obtained by the onset of some degradation process. In principle, according to the order given by the arrows, each energetic form is able to absorb a second energetic form less advanced on the evolutive diagram. It happens that these forms obey the rule of natural classification, whose main features are in our subconscious, and that sometimes, we must learn to recognize and codify. In this way a limited number of pertinent features characteristic of each form appear, however which are sufficient to allow us to recognize forms.

3.2. A general property of perceptual mechanisms. It seems that exteroceptive sensibility possesses at least 10 properties[1] that we can find in each of the five senses. The first of these properties is a global morphological one. The second is also of a morphological nature, and in a certain sense complements the first property.

According to the second property, it would seem that the general scheme for recognizing a form involves an emmitting agent E, the informative form F which is to be recognized (F is in part the mould of E), and a receptive agent R, whose form is to be easily identified with the form of E, so that it must be shapped by F, in-formed by F.



The form F is emitted by E: for instance, in the physical world a tuning fork, set into vibration, spreads a copy of its form around itself, which propagates, strikes and puts in movement a second tuning fork, identical with the first one. When the form F is emitted by R, R possesses within itself the scheme of a standard form that it projects on E to see to what extent E is an interesting form for it. A typical example of such a situation is of the hand able to take the fundamental spherical shape, and to recognize forms homeo morphic to S^2, even those presenting corners, as for instance cubes.

One should remark that the problem of form recognition is both of a morphological or properly topological nature (homeomorphy of forms), and of a metrical nature (isotopic cobordism, keeping constant the absolute values of curvature, but inverting the signs).

3.3. A possible scheme for the construction of some perceptual mosaics. Recognition by smell of biochemical spatial forms is a classical example of propagation of forms. The dynamical aspects of these propagations are yet to be discovered: the geometrical correspondence to the notion of chemical affinity is almost unknown, as well as the effects of resonance between arms of molecules. The phylogeny of stereochemical sequences, the one of the concatenation of elementary forms in a global stable form, are unfortunatly very ill known. However, it is possible to give a very general scheme of differentiation that could explain the formation of such chains.

According to this scheme, a global form G is characterized by a potential. Its value depends on parameters whose value are under the influence of the surroundings. For some values of the parameters, the potential falls abruptly. This fall of potential leads to a breaking of the initial global morphology into secondary morhologies; for instance E, R, F, form the constituents of a chain of a perceptual mosaic.

The classification of stereographic forms by purely mathematical means ignoring the phylogenetic past would be in some way artificial. That may be the reason why this classification seems actually so difficult. If one wants to forget the past, one is obliged to take into account the properties of the elementary chemical constituents, thus of elementary morphologies which are the stones of the stereochemical edifice.

3.4. **The dynamical visual space.** In the former situation, we find once more an ordinary property of the recognition of complex forms. This recognition frequently leans on a multitude of local geometrical processes of similar types that have to be linked up in order to obtain a coherent general view. In man, the construction of the visual image is made according to this method of the mosaic, of the geographical puzzle whose pieces are set together in such a way that the concatenation of forms is realized. The visual systems, by the reaction it shows to local differences of light intensity and colors, practically defines the zero-section of the tangent fiber space associated with the object it is looking at. This fiber space is built from an atlas consisting of a small number of local charts; each local chart is centered around a singular point of the ocular pathway that, approximatively, plays the role of the nerve, the 1-skeleton of the visual atlas.

Let us insist on the dynamical character of the construction of the visual image, built from a multitude of small light gradients. Let us admit that this dynamical visual fiber space, V, which is present at the level of ganglionary neurons, remains invariant until the level of the superior colliculus and of the lateral geniculate bodies. At this level, a part of the visual energy, the one that very likely corresponds to the second tangent fiber space of the image, is sent to the motor centers, while the other part goes to the visual areas, where integrative phenomena occur. Some charts of V would be projected on some integrative neurons which so realize a dynamical sub-fiber space of V. By projection, the picture of each chart must lose its precision; but since the original chart can be projected on different integrative neurons, the overall impression remains unchanged, possessing as much detail as before.

3.5. **Differentiation of spatial perception.** It is easy to recall the past evolution of spatial perception, by following the evolution of the presence of semi-circular canals, which play a primordial role in the equilibration of the living being in its environment. Successively, we find one semi-circular canal in the Myxine, two in the Lamprey, three in the Batracians.

We may think that the Myxine has an uni-dimensional space perception, the one of light and gravity. The Lamprey would have already got a bi-dimensional spatial perception, defined by the vertical and the horizontal. We know that the visual neurons of vertebrates are particularly sensitive to these two directions. We have just seen the importance of the vertical with regards to the Myxine. The development of the horizontal perception was followed by the unlocking of the rotational group of the head, which in fish operates in the horizontal plane. These considerations on the phylogeny of visual development show that it is quite normal for visual sensitive neurons in these two privileged directions to be the most numerous.

The perception of the third dimension, the one of depth, of the distance from the subject, is undoubtedly more recent. If one is fed simply by opening the mouth, the presence of a mechanism that evaluates distances is of no use. On the contrary, such a mechanism is necessarly present when one has to go and capture the prey by oneself.

If, as it is now become classical, we associate an epigenetic landscape *á la Waddington* with any embryological and phylogenetical development, then the spatialization of perception would be described, at least locally in the landscape, by the hierarchical unfolding of the singularities: fold, Riemann-Hugoniot, and butterfly.

3.6. **Perception of the visual space.** A good geometrical model of visual color perception is actually available [3]. Probably, this model can be applied to the auditive sound perception. However, until now, no relevant model of the perception of the visual space V has been set up. Previous models (Luneburg, Blank, Hardy, Balsev, Leibovic, ...) do not sufficiently fit experimental facts.

To build an appropriate model of this perception, it does not seem very judicious to give too great importance to the effects of some visual experiments, well known as geometrical illusions. These experiments are always done in an impoverished visual context — points and lines on a uniformly colored background so that the retina does not work in the usual conditions of a very rich environment. It is thus possible to explain this visual illusions, by appealing to hydrodynamical models, characterized by the presence of shockwaves along which the perception of these illusions is organized.

The problem has to be taken rather ex abrupto. Obviously, the visual space V is a topological space which is open, compact, simply connected, and contractible. Naturally, we want to put a metric on V. Let us first remark that this metric may change from one subject to another, on the one hand according to the state vision of the subject, on the other hand according to his neuro-psychological state. Epileptics, for instance, can see the objects nearer and larger than they are in reality; for schizophrenics, the inverse situation occurs [2]. At last, this metric depends on climatic and illuminative conditions; however V remains invariant within limits of variations of these conditions that we shall ignore.

We shall suppose that, for a given normal subject, the angle θ (one minute on average) under which the discrimination between two closed points can be done, remains constant: by an aproximation of Thales theorem, in the direction j, $tg\theta = \frac{dx_j}{x_j}$. For each individual i, at time t, there must exist real coefficients $\alpha_v(i,t)$, $\alpha_h(i,t)$, $\alpha_p(i,t)$ (v, h, p, respectively for vertical, horizontal, depth) so that V is endowed with the metric:

$$ds^2(i,t) = \alpha_v(i,t)\left(\frac{dx_v}{x_v}\right)^2 + \alpha_h(i,t)\left(\frac{dx_h}{x_h}\right)^2 + \alpha_p(i,t)\left(\frac{dx_p}{x_p}\right)^2$$

this is the Helmholtz — Stile metric.

Distances x_j are evaluated from the vanishing point O of the observer. O plays an analogous role as the vertex of a cone. The coefficients α_j have to be determined by experiment. As the effects of drugs show, we may suppose that these coefficients can be moved on a Riemann-Hugoniot surface S within a neighbourhood of the singular point of S, for a subject without any psychological trouble.

4. ON INTERNOCEPTIVE PERCEPTION

We shall only consider here upon the hypothetical mechanism of conscious percepttion of actions, which is not very different from the perception of proper thoughts, at least in its principle.

We can associate with each individual or collective subject, a mental space of representation, which is a fiber space. The basis of this fiber space is an image of the subject's territorial, i.e. a spatio-temporal domain on which the subject has some influence. The fiber F_u above each point u of the basis, is a pluridimensional space of qualities. At each time t, the subject defines a point f(u,t) on this fiber; f(u,t) represents the energetical interest of u', where u' is the counter-image of u in the ordinary ambient space. The set of points f(u,t) can be a surface, more generally a Riemaniann variety Σ_t, on which the representative point of the subject, σ_t, can move, under the influence of a kind of gravity field; generically, σ_t will reach an extremum of Σ_t. We can suppose Σ_t defined by the unfolding of a global potential, a Lagrangian; the temporal evolution of the parameters defining Σ_t can lead to the possibility of fast changes in the position of σ_t.

The nervous motor space M receives an image Σ_t' of Σ_t. When the energy of σ_t', image of σ_t in M, reaches some threshold value, one or several motor are put in action. M is a product of different elementary motor spaces, amongst which is the motor space of vocal emissions. When some threshold is reached which can set going the phonatory act, by coupling with the auditive space, an activation of the interval auditive mechanism occurs. It is then said that we get conscious of our action.

Any attentive behaviour results in a lowering of perception thresholds of perceptive acts, which implies a local modification of perceptive mechanisms. The introduction of such modifications by means of pathways of attention whose existence is here postulated, needs a an expenditure of energy; in other words, mental or careful work tires the nervous system of the individual — a fact some people might know.

5. CONCLUSION

To these geometrical approaches of problems of perception, one might reproach the absence, in general, of references to old or future experiments, the frequently hypothetical character of our very global constructions, whose validity is not always easy to test. To these arguments, we shall answer that only geometrical vision has really allowed the advancement of mathematics, the concept of important models in physics (cosmology, electro-

magnetism and optics); therefore, it might not be unreasonable to want to introduce such a perspective in the study of life events. We would also like to stress how the geometrical procedure, by the simplicity and the universality of its language, makes easy a synthetic understanting of various processes, apparently very different one from the other, and in the same time emphasizes the significance of vague concepts.

Geometrical explanation gives always rise to a feeling of evidence. But there is no evidence without truth. Truth if of a geometrical essence.

References

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