SPATIAL PERCEPTION AND CENTRAL NERVOUS SYSTEM SYMMETRY

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Hughlings Jackson called attention to the remarkable fact that the nervous system is double, and he admonished future neurologists to consider the significance of this construction. Nevertheless, the fact that in each human there are two complete nervous systems — a right and a left — has been largely neglected by the neurophysiologists, and has been explored primarily as a consequence of unilateral cortical trauma or surgery. From these studies it is clear that the human cerebral cortex is functionally differentiated right-left and that control of certain specialized activities, particularly those relating to symbolization, resides primarily within a single hemisphere. The anatomical or biochemical basis for this lateral differentiation has not been elucidated.

One consequence of complete symmetry of central nervous system function was suggested by Ernest Mach when he postulated that some asymmetry of proprioception might be responsible for our ability to distinguish right from left. Thus, an animal whose nervous system was, indeed, truly bilaterally symmetrical could not diferentiate between stimuli arriving at homologous points. Such an organism would be able to make only mirror image responses to homologous right and left stimulation. For example, a cat can be taught to choose a right door for right tactile stimulation and a left door for homologous left tactile stimulation or to distinguish a circle from a square for tactile stimulation of the head versus the tail. But a cat cannot be taught to distinguish a circle from a square for homologous right and left stimuli. Likewise, Pavlov and his students were unable to train dogs to salivate when touched on the right side of the body, but not to salivate when touched on the homologous left point. The animals continued to respond equally well to either left or right stimulation regardless of differential reinforcement.

Thus, the human owes his ability to distinguish right from left to the asymmetry of his nervous system. In the same way, an organism can distinguish front from back or head from tail only by virtue of the asymmetry of his nervous sytems in those dimensions. Awareness of spatial position is, therefore, dependent upon asymmetry of the perceiving system, and evolution consists of increasing that asymmetry.

It is possible to calculate the increasing amount of spatial information with the development of asymmetry by applying the following formula for the definition of information:

$$\text{Information} = \log_2 \frac{\text{Probability of a given response before stimulus is applied}}{\text{Probability of a given response after stimulus is applied}}$$

By using this formula, quantity of information is obtained in "bits" (binary digital units).

The following series of "Euclidean" organisms, each consisting of 64 stimulable points, and differing only in the degree of symmetry of the nervous system, will illustrate the principle:

1. The spherical organism is the most primitive and has maximum symmetry. Whichever of its 64 points is stimulated, the response, with respect to the site of the stimulus, is always the same. Thus each point is indistinguishable from any other point, and the spatial information conveyed by the stimulus is:

$$\text{Information} = \log_2 \frac{1/1}{1/1} = 0 \text{ bits}$$

2. The radial organism arises from the spherical by development of an axis of asymmetry. It might consist of 8 circumferential bands, each containing 8 stimulable points arranged symmetrically around the circumference. However, the response to a stimulus applied at one band is uniquely different from the response to the same stimulus applied to any of the other bands, but is the same for all points within any single band. Thus, the organism can distinguish 8 spatial positions on its surface and the spatial information conveyed by stimulus is:

$$\text{Information} = \log_2 \frac{1/1}{1/8} = 3 \text{ bits}$$

3. The bilaterally symmetrical organism arises from the radial by development of a second axis of asymmetry at right angles to the first.

Thereby it acquires a front and a back, as well as a head and a tail. Each side contains 32 stimulable points, and a unique response is elicited by a stimulus applied to any one of the 32. However, the responses to stimulation of homologous points are mirror images and, therefore, identical when referred to the site of stimulation. The spatial information conveyed by a stimulus is:

$$\text{Information} = \log_2 \frac{1/1}{1/32} = 5 \text{ bits}$$

4. The completely asymmetrical organism consisting of 64 stimulable points, each of which elicits a unique response, represents the maximum spatial information transmitting system:

$$\text{Information} = \log_2 \frac{1/1}{1/64} = 6 \text{ bits}$$

Man is somewhere between organisms 3 and 4 because he can distinguish right from left, but he frequently makes mistakes. His brain has only just begun to develop a functional difference between the two hemispheres and his universe has only dimly achieved three dimensions.

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