From Infinities to No-thing: An Exploration of Brain Function

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ARISTOTLE defined man as the rational animal. Man's happiness, therefore, depended not only on pleasure, the fulfillment of needs, but also on the fulfillment of his rational capacities. Rationality implies the ability to analyze: The root from which the word rational is derived is also the root of ratio, divide.

In keeping with the Aristotelian view, and especially successfully since the Renaissance, Western man has cultivated his rational, analytic capabilities. He has, for the most part, developed knowledge, science, at the expense of wisdom, finding his universe filled with particulate detail which failed to provide an integrated view of the whole.

Throughout this period, philosophers have cautioned against this one-sided approach to happiness. Aristotle had not eschewed pleasure, he had stated only that pleasure was not enough if man were to be truly human. In our own century

Abraham Maslow made explicit the hierarchical nature of man's requirements for happiness: Rational fulfillment presupposes the fulfillment of more basic needs.

Meanwhile, phenomenological and existential thinkers began to point out that man-in-his-universe might not appear the same as man, the center of his universe. Jung brought an emphasis on spirituality to bear on the behavioral sciences—spirit defined in terms of infinities; universals; the collective (therefore undivided, unrational) unconscious; the instinctive, shared aspects of the human potential. And even behaviorists began to note that behavior is predicated on an interaction between man as an organism and the environment of that organism. Behaviorists opted to emphasize either organism *or* environment in this duality; but they need not have taken this reductive path, and at least some may, in the future, come more into concert with the phenomenal-existential approach.

These problems regarding part *versus* whole also come to a focus in the mind/brain issue. Over the past two centuries it has become clear that man's rationality and his mental functions in general are especially dependent on his brain. Thus, what makes man human is his brain. However, controversies have raged as to whether mental, and therefore brain, functions were all of a piece or whether they were divisible into faculties, separate processes that had to become integrated by some superordinate homunculus or executive "ego". In the neurosciences the separate-parts view reigned as the sole explanatory principle, apparently undisputable, until recently. Now there is a body of evidence to show the relevance, in at least two problem areas, of a sophisticated and precise wholistic approach. Let us look at these two areas and see what they have to offer in shaping our view of human nature.

WISDOM AND INFINITY

The brain regulates not only the body's interactions with the surrounding world but also the various bodily processes, man's basic physiological needs per se. Many of these processes, even those within the brain itself, are cyclic and rhythmic. The heart beats, peristaltic waves of gut aid digestion, sex hormones wax and wane, nerve cells spontaneously fire at periodic intervals. The regulation of these cyclicities has been familiarized under the concept "homeostasis"—the idea of a steady state achieved by a negative-feedback mechanism which turns down the production of a substance or discharge as it accumulates.

In my laboratory we have found that the part of the brain that regulates these bodily cyclicities also copes with recurring regularities in environment. For both internal and external regulations a special form of memory is invoked which monitors the substances and episodes involved. The nature of this memory (ordinarily called "episodic" or, when brief sequences are involved, "short-term" memory) has puzzled scientists for many decades. Recently, however, a physical scientist by the name of Spencer Brown (1972) faced a similar problem in engineering, provided a solution and saw the wide-ranging implications of his solution.

Spencer Brown's problem was to deal with oscillations of the wheels of a railroad train which suddenly came to a halt in a tunnel. To solve the problem of how many such oscillations had taken place (thus to identify how many wheels had actually traversed rather than oscillated across a sensor) Brown had to utilize an imaginary number ($\sqrt{-1}$) in the Boolean (binary) algebra. The reason for this was that the number of oscillations could be infinite, and thus no simple "real" solution to the problem existed.

Cyclicities are not bounded. The ordinary logic of real-number mathematics is therefore inadequate to deal with the problem. Take a line of infinite length (or a cycle of infinite length) and divide it in half. You now have two lines (or cycles) of infinite length. And you also have the *fact* that a half line (or cycle) equals the whole. Whether you want to attend to or use the half or the whole depends on circumstances, on what else is going on, the context in which use or attention is demanded. As Solomon so *wisely* judged, when there is a property dispute, dividing a roast in half may be perfectly equitable, but dividing a baby is not.

Our work has shown that the frontal lobes of the brain, that part which was once so freely severed in the procedure of leukotomy or lobotomy, is concerned in making such episode-specific, context-sensitive judgments. Wisdom, therefore, is dependent on an entirely different brain mechanism from that which allows us to accumulate knowledge. Knowledge is categorical; knowledge depends on identifying differences among a finite set of alternatives. Knowledge is comprised of information.

Wisdom, by contrast, rests on processing infinities. Paradoxes abound: Halves equal wholes when they are lines, but not when they are babies. The greater a hunger, the greater the satisfaction. The greater the hunger, the greater the disappointment. Satisfaction equals disappointment? Sometimes. The use of an imaginary number to solve such problems mathematically indicates that there are no *single* solutions in this domain. The appropriate behavior depends on the context in which the problem arises. There is no such single solution to being hungry—eating more after a Thanksgiving dinner will not take care of recurring appetite the following weekend nor stave off starving at Christmas.

In his search for knowledge man has paid little heed to understanding the roots of wisdom. I have at times voiced to my scientific colleagues some of the problems discussed in the paragraphs above, and their answer has always been either that one cannot deal at all with infinities or that one simply sets arbitrary bounds and then solves the problems in that fashion. But these answers are inadequate. There is a domain of everyday experience and behavior which depends on our deep understanding of infinities and paradoxes, and the rules of operation in this domain are very basically different from those that we ordinarily employ to acquire and use knowledge.

Not that this domain has been completely ignored. Matte Blanco in a volume entitled *The Unconscious as Infinite Sets,* published in 1975, tackles the issues involved. Gregory Bateson (1972) has faced the problems, as have his students and colleagues, especially with regard to interpersonal communication. (1967). But these are the exceptions. Formal schooling of necessity ignores wisdom, because we know so little of its formal structure. Perhaps recognizing that the problem exists can be the first step in facing it. Perhaps no more can be done than to distinguish wisdom and its base in infinities from knowledge based on rationality, i.e., division, categorizing, particularizing. Or perhaps this statement of the problem will be but a beginning.

WHOLISM AND NO-THING

The second area of inquiry which has yielded to a precise wholistic formulation has to do with the brain mechanisms involved in perception and memory. One of the major problems of brain function that has deterred behavioral scientists and philosophers from paying heed to the developments in the neurosciences has been the lack of any plausible model for memory storage. Lashley (1950) dramatized this problem in his statement, made less than three decades ago, that after a lifelong search for the neural substrate of memory traces he had reluctantly come to the conclusion that despite behavioral evidence to the contrary, learning was just not possible. The basis for this statement is that cutting brain pathways or even removing large pieces of brain does not remove any particular memory or set of memories. In some fashion or other the input to the brain from the senses must become distributed before it is stored.

Over the past decade the deficiency of our ability to provide a plausible model for a distributed store has been remedied. Dennis Gabor (1948) gave a precise mathematical formulation for such a store, which was subsequently implemented in the process of holography. A hologram is made on a photographic film by storing directly the waves of light reflected by or transmitted through objects without bringing them to focus by a lens. Gabor's mathematic formulations are called spread functions because they describe the spreading, or blurring, of every point of light over the surface of the film. The blur is not haphazard, however. It is composed of the waves created by each point of light, much as such waves are created by a pebble striking the placid surface of a pool. Many simultaneously striking pebbles will ruffle the water's surface in patterns of ripples, each composed of expanding wave fronts. The hologram is a frozen record of patterns of ripples. Gabor's major contribution was to show that focused images of the source of the ripple patterns could readily be reconstructed from the hologram. The technique of image reconstruction demands only the knowledge of how the blurred image was produced. In our space program such blurs occur because the photographic satellite is speeding by its target; subtracting the speed from the photo by computer provides the image. Similarly, performing the inverse transform on a hologram (by computer or optical system) will constitute a focused image from the distributed (spread) store.

It became evident that the hologram could provide the long-sought plausible model of memory storage in the brain. In addition to the distributed nature of holographic memory and the ready mechanism of image reconstruction that it made possible, holography provided additional important advantages. Larger amounts of memory could be stored than by any other technique; an associative function characterized the holographic process; and reconstructed images did not fall on the holographic film, but were projected away from it, just as we do not see images on the surface of receptors or the brain.

A caveat must be noted at this point. The holographic model is meant to handle only one aspect of brain function: the distribution of sensory input before storage and the mechanism of image construction and reconstruction. The model does not deal with categorization, with the response mechanisms of pattern recognition, especially those of identifying objects in space, or with the formation of signs and symbols. It is gratifying to have found a plausible model for distribution in memory and image reconstruction. Gratification should not lead to overgeneralizing and extending the model to areas of inquiry where the it is patently not applicable.

Initially, of course, the neural hologram was but a metaphor. Over the past decade, however, more and more evidence in support of a rigorous neural holographic model has been obtained in laboratories as distant from each other as Leningrad, Pisa and Stanford. The major contributions have been made by a group headed by Fergus Campbell and John Robson at Cambridge University (1968); Daniel Pollen at Harvard (1974); and Russell De Valois at Berkeley. (1978). What was needed was evidence that the brain operated as a frequency analyzer—an analyzer of the vibrations, the waves, that compose the frequency spectrum of physical energies. Ohm (1843) and Helmholtz (1867) had already performed experiments almost a century before to show that the ear and auditory nervous system operated as a frequency analyzer of sound. Bekesy (1967) using equations similar to Gabor's, constructed sets of mechanical vibrators to model the cochlea of the inner ear. He then showed that this mechanical model could be applied to the skin and that one could sense such stimulation as if it were at a distance, in a manner similar to that used in stereophonic high-fidelity systems to project the sound image away from the source speakers. Further, work from my own (1971) and other laboratories (Bernstein, 1967) indicated that the motor system is also organized to analyze periodic stimulation from the muscle system.

What remained to be shown was that the visual system operated in the frequency mode to analyze spatial relationships in constructing spatial images. This has now been accomplished in the laboratories noted above by impaling single cells in the visual system of the brain and showing that they do encode in this mode, by virtue of being tuned to one or another octave of spatial frequency. The ensemble of cells thus forms a microstructure which acts as a frequency filter—in short, a hologram. As Campbell has said, the current contribution is to show that the eye analyzes the spatial distribution of light much as the ear analyzes the temporal distribution of sound.

Thus, evidence has accumulated to show that one operation the brain performs is to resonate to the periodicities and vibrations in the energy spectrum of the environment. Images of objects are then constructed and reconstructed from the store (probably protein) based on this distributed resonating filter—the neural hologram.

This development of our understanding of brain function mirrors that encountered in quantum physics during the earlier part of the century. In studying the microstructure of the fabric of the material universe, physicists were faced with smaller and smaller units, particles which behaved more and more oddly. In fact, in some situations the description of their behavior made "them" appear to be waves rather than particles. Finally, within the nucleus of atoms particles are only temporarily constituted when energy patterns, wave forms, interact in certain ways. At least one eminent physicist, David Bohm (1971; 1973), has suggested that a hologram like "implicate" order underlies the particulate material universe.

It is important to understand fully the nature of this suggestion. The finding of a nonparticulate base of the physical world does not deny substance and reality to the ordinary world of appearances. Our discovery of the fact that the world is round does not deny its local, everyday flatness for use in walking, building, etc. Our discovery of the rotation of the earth around its axis and its trajectory in space does not do violence to our everyday readiness to rest and sleep without worry that we shall be spun away from our berth. What we want to know is how the world of appearances comes to be, how it is related to these other "realities" that our science has discovered: Just how shallow is the curvature of the earth, how do centripetal gravitational forces work, how are particles formed from hologram like flows of energy?

But another aspect of these discoveries and their interpretation, with regard both to the microstructure of the brain and to quantum and nuclear physics, is the primacy of the distributed, extended domain over the particulate. Or if not primacy, certainly complementarity exists between the two domains. In either case there is a very basic level of organization in brain and universe in which "things," as such, do not exist. Things are space bound and time bound. In the holographic frequency domain such bounds do not exist.

This, then, is a domain of no-thingness. No-thingness is not a void. The holographic universe is packed with energy, but particles, things, must be derived in order to constitute the ordinary and complementary universe of appearance. Whether derivation occurs external to and independent of sense organs and brain is at this reading difficult to gauge. As Wigner (1969), another eminent physicist, has pointed out, modern microphysics rests on establishing relationships between observations, not between observables. This is due to the fact that changes in observational technique change the observations in non-trivial ways (the Heisenberg principle).

Thus, experimental studies of both organism and environment have unveiled a wholistic, non-divided universe in which no-thing can be located, because everything becomes distributed and extended in time and space.

Infinity and no-thing! What strange aspects of nature have we humans come upon. The mathematics of ∞ and O have challenged thoughtful investigators for millennia. Now we find these same characteristics not only in the physical universe but also in our own brains. *Our* very nature must thus be formed, in part at least, in terms of these organizations. Western man has triumphed over the obstacles to happiness in his environment. But at the same time he has barely begun to fathom his own nature and to form a social structure consonant with this nature. Science, especially, has eschewed coping with the nonparticulate, with the nonobjective (i.e., anything which cannot be understood in terms of objectifying, making objects of). Nor has science been tolerant of observations, such as precognitions and telepathy, which do not fit into the ordinary world of appearances and of space-time coordinates. As we have noted, however, the holographic frequency domain collapses time and space into simple densities of occurrences. Perhaps those who experience paranormal phenomena tune in on this domain. Jung called such tuning-in "synchronicity," and Lila Gatlin (1978) has used information-measurement mathematics to demonstrate how synchronicities can occur. What has been missing is a scientific base for understanding such paranormal phenomena. Only when such a base is solidly achieved can we evaluate their "objective" validity.

My message here is that we ought to introduce into our educational system at least some acquaintance with the logical paradoxes of infinities, with non-objective no-thingness, with these forms of wholistic thinking, lest we ignore the very depths of the nature of man. Surely, it is the nature of man to be rational, but I believe it is also his nature to attempt to experience the extended universe of no-thing and to aspire to the wisdom of the infinite.

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