T-105

What the Fuss is All About

KARL H. PRIBRAM

The Physical

David Bohm in his book on *The Special Theory of Relativity* has an appendix on Perception. In this appendix he covers problems dealing with the psychology of appearances, especially James Gibson's findings in an extended series of experiments. These experiments utilize two dimensional displays on cathode ray tubes which are perceived as three dimensional figures. Gibson argues from his findings that three dimensional perception is "direct," i.e., immediate and that all other forms of knowledge and the world are derived from this immediate reality.

In a paper in which I take issue with Gibson on the "directness" of appearances, I describe the constructional brain processes which are involved even when perceptions appear to be immediate. An example from everyday life is the immediacy of our awareness of a projected three dimensional acoustic image in stereophonic high fidelity reproduction of music. We know the sources of the sound to be the speakers but we also know that by adjusting the phase relationships between acoustic waves generated by the speakers we can move the sound away from the two sources, to in between the speakers or in front of them.

Our ears and acoustic nervous systems (re)construct the sound to be perceived in a location we know to be incapable of producing that sound. Which then is the reality of the situation, the perceived appearance or what we know to be the physical arrangement that gives rise to the appearance? Gibson has emphasized the reality of appearances and the primacy of that reality. Most other scientists, however, when they are asked what they mean by the "real" world would answer that they mean the world of physics. If pushed, they would even describe that world as being made up of material objects and the interactions among these objects. In the example given, they would give primacy to the reality of the sound (re)producing stereophonic high fidelity apparatus, not the perceptual awareness derived from the operations of that apparatus.

Pursuing this "objective" reality of the physical universe, I began to inquire into the investigations of modern physicists. Immediately, I ran into the writings of David Bohm, Bohr, Einstein, Heisenberg, Wigner, Weizsacker, and others. Bohm had worked with Einstein who was occupied in a search for a unified field theory because he did not like the probabilistic statistical view that at bottom the physical universe is composed of essentially haphazard movements of minute objects, particles such as electrons and photons. Einstein expressed this concern in his statement that he did not believe God played dice with the universe. Bohm conceptualized the dilemma by suggesting that beyond haphazard appearance lay a domain of constraints, a set of "hidden" variables which, when uncovered, would provide a consistent non-statistical basis for the apparently haphazard comings and goings of individual particles.

Bohr had ennunciated the principle of complementarity to deal with some of these same problems. He suggested that particles and fields were complementary views of the same sets of occurrences and his followers have come to believe in a basic reality opposite to that held by Einstein and Bohm. The so called "Copenhagen Solution" (Bohr was a Dane) insists that the wave function—the field characteristics of microphysics—describe an envelope over the statistical perturbations of particles. It is this view of the primary reality which Einstein and Bohm continued to counter.

Heisenberg, Wigner and Weizsacker make still another and perhaps even more profound point. Heisenberg notes that the complementary view of the basic physical structure of the universe—particles *vs* waves—are derived when different observations are made, different techniques are used, and different experiments are performed. Each experiment yields consistent results but the results of some are incompatible with those of others. Complementary views are based on disparate sets of data. Heisenberg argues in his famous principle that there is therefore no way of knowing which of the views is the more basic.

Wigner has conceptualized this line of reasoning in the statement that modern microphysics studies the relationships between observations not between observables. An observable is an observation that remains consistent, constant over a range of different views. Gibson, the psychologist, speaks of such constancies as invariances or "information," and Weiszacker squarely faces the conclusion, as does Bohm, that modern microphysics must deal with information defined *psychologically*, i.e. through behavioral observations.

Thus modern physicists and modern perceptual psychologists have converged onto a set of issues that neither can solve alone. If the psychologist is interested in the nature of the conditions which produce the world of appearances, he must attend to the inquiries of the physicist. If the physicist is to understand the observations which he is attempting to systematize, he must learn something of the nature of the psychological process of making observations.

The Mental

As a brain scientist, I have come into the midst of this convergence. Brain is an essence of the material world; still it is an essence of which observations are constructed. An easy conceptualization would suggest that perceptions are emergent properties of the interaction of brain (and body) with the physical universe. Much as gravitational and electromagnetic forces are composed of the interactions among material objects and particles, so perceptions and other mental phenomena are composed of the interactions between brain (senses and body) and its surrounding "real" world.

At one level such an easy explanation is, of course, tenable. But deeper penetrations into the ideas reviewed above suggest another equally plausible explanation. Relationships among observations *are* mental phenomena since observations and perceptions are mental. Perhaps the very fundamental properties of the universe are therefore mental and not material. Nuclear physicists remind themselves of this possibility when they attribute charm, colors and flavors to their "relationships among observations," the quarks, bosons and other most elementary particles that constitute the nucleus of atoms. And from time to time philosophers such as Leibnitz and Whitehead have proposed panpsychic ontologies to account for similar views obtained by following through to a logical conclusion the reasoning of their mathematical insights into the basic order of the universe.

The following statements place these two basic views into succinct apposition:

1) Brain by organizing the input from the physical world, as obtained through the senses, constructs mental properties.

2) Mental properties are the pervasive organizing principles of the universe, which includes the brain.

Paradoxically, almost all behavioral and neuroscientists would today subscribe to some form of statement one, while, as noted above, statement two reflects the belief of many of the most influential theoretical physicists. Mathematicians have faced the dilemma more directly: how is it that the operations of their brains so often describe faithfully the basic order of the universe they perceive?

Whenever thoughtful inquiry produces an impasse, it is reasonable to ask whether the questions being asked are being properly phrased: In the present instance, could it be that the properties derived from the relations between organism (brain-senses-body) and environ-

ment (physical universe) that are called mental and those that are derived from relations among observations of the physical universe, though also called mental, are disparate? If so, the problem would be essentially a semantic one—the same name used for different properties. In view of the fact that the proponents of the two views are extraordinarily sophisticated thinkers, this simplistic resolution of the problem most likely to be wrong. Those who believe mind and consciousness to be extended in the universe really do mean to refer to the same set of properties that are referred to by those who see perception, attention, consciousness, etc. as, primarily, manifestations of brain functioning. The same naming indicates that the same meaning is intended.

But another possibility can be entertained which does not do violence to intended meaning. Could it be that one aspect of organism-environment relations and one aspect of relationships-among-observations shows a commonality which has been generalized to the entire range of mental properties? Such overgeneralization (or lack of differentiation) is a well known attribute of thought processes, and much of scientific and philosophic inquiry is devoted to "unpacking" sets of concepts which, though related, differ from each other in some non-trivial fashion. I believe that in the present instance there is evidence that "unpacking" of the concept "mind" is warranted.

The Neural

The evidence comes from understanding the nature of the brain mechanism involved in constructing perceptions—the mechanisms necessary to prehend the world of appearances. The story begins, not with perception however, but with memory. Specific memories are incredibly resistant to brain damage. Removing a hunk of brain tissue or injuring one or another portion of the brain does not excise a particular memory or set of memories. The process of remembering may be disturbed in some general way, or even some aspect of the general process may be disrupted. But never is a single memory trace of some particular experience lost while all else that is memorable is retained. This fact has become well established both through clinical observation in man and through experiments on animals. Thus in some way or other memory must become distributed—the experienced input from the senses becomes spread over a sufficient expanse of brain to make the memory of that experience resistant to brain damage.

Until recently, brain and behavioral scientists could not conceive of any mechanism that was consonant with the facts of brain anatomy and physiology and at the same time spread sensory input sufficiently to account for the distributed memory store. Now a plausible mechanism has been discovered.

In the late 1940's Dennis Gabor suggested that the resolution of electron microscopy could be enhanced if instead of storing images directly, the photographic film would be exposed to the patterns of light diffracted (filtered through or reflected from) by the tissue to be examined. Gabor's suggestion was formulated mathematically. Only many years later in the early 1960's was his suggestion realized in hardware. These hardware realizations made it obvious that images of the objects that had initially diffracted the light could readily be reconstructed. Thus object → wave storage → image construction could be seen to be a simple linear process. Furthermore, Gabor's equations showed that the identical mathematical transfer function transformed object into wave storage and wave storage into image! The storage of wave patterns is thus reciprocally related to the imaging of objects!! The wave functions are transforms of objects and their images.

Gabor named the wave pattern store a *hologram* because one of its most interesting characteristics is that information from the object becomes distributed over the surface of the photographic film. Each point of light diffracted from the object becomes blurred and is spread over the entire surface of the film (the equations that describe this are called spread functions), as is each neighboring point of light. The spread is not haphazard, however, as the blur would lead one to believe. Rather, ripples of waves move out from the point of light much as ripples of waves are formed when a pebble strikes the smooth surface of a pond of water. Throw a handful of pebbles or sand into the pond, and the ripples produced by each pebble or grain will crisscross with those produced by the other pebbles or grains, setting up patterns of interfering wave fronts. The smooth mirror-like surface has become blurred, but the blur has hidden within it an unsuspectedly orderly pattern. If the pond could suddenly be frozen at this moment, its surface would be a hologram. The photographic hologram is such a frozen record of interference patterns.

It seemed immediately plausible that the distributed memory store of the brain might resemble this holographic record. I developed a precisely formulated theory based on known neuroanatomy and known neurophysiology that could account for the brain's distributed memory store in holographic terms. In the dozen or so years since, many laboratories including my own have provided evidence in support of parts of this theory. Other data have sharpened the theory and made it an even more precise fitting to the known facts.

Essentially, the theory reads that the brain at one stage of processing performs its analyses in the frequency domain. This is accomplished at the junctions *between* neurons not within neurons. Thus graded local waxings and wanings of neural potentials (waves) rather than

nerve impulses are responsible. Nerve impulses are generated within neurons and are used to propagate the signals that constitute information over long distances via long nerve fibers. Graded local potential changes, waves, are constituted at the ends of these nerve fibers where they adjoin shorter branches that form a feltwork of interconnections among neurons. Some neurons, now called local circuit neurons, have no long fibers and display no nerve impulses. They function in the graded wave mode primarily and are especially responsible for horizontal connectivities in sheets of neural tissue, connectivities in which holographic-like interference patterns can become constructed.

Aside from these anatomical and physiological specifications, a solid body of evidence has accumulated that the auditory, somatosensory, motor, and visual systems of the brain do in fact process, at one or several stages, input from the senses in the frequency domain.[1] This distributed input must then, in some form, perhaps as changes in the conformation of proteins at membrane surfaces, become encoded into distributed memory traces. The protein molecules would serve the neural hologram in the same way as oxidized silver grains serve the photographic hologram.

The explanation of the fact that specific memory traces are resistant to brain damage (remembering demands only that a small part of the distributed store remain intact in the same way that images can be reconstructed from small parts of a photographic hologram) has been only one of the contributions of holographic theory. Characteristics of the experience of imaging have been explained in an equally powerful manner. The projection of images away from their sources of origin has been demonstrated to result from processing phase relations (just as in the stereophonic audio systems described above). Simulations of image processing by computer have found no technique other than the holographic to provide the rich texture of scenes such as those that compose our experiences. And the complicated computations that go into three dimensional x-ray imaging by computerized tomography have relied heavily on the fact that such computations (mostly correlations) are performed readily in the frequency (holographic) domain.

The Philosophical

But perhaps the most profound insight gained from holography is the reciprocal relationship between the frequency domain and the image/object domain. Recall that the fundamental question that is under consideration is whether mind results as an emergent property from the interaction of an organism with its environment, or whether mind reflects the basic organization of the universe (including the organism's brain). Images are mental constructions. They result from processes involving the brain (object), the senses (objects) in their interactions with the environment (considered objectively, i.e., as objects, particles such as photons, electrons, atoms, molecules and the objects of the reality of appearances). Images (one aspect of mind) are thus emergents in any objective, object-i-fying philosophical formulation.

But the process of image construction involves a reciprocal stage, a transformation into the frequency (holographic) domain. This domain is characteristic not only of brain processing, as we have seen, but of physical reality as well. Bohm refers to it as the implicate order in which points become enfolded and distributed throughout the brain.

In the implicate, holographic domain, the distinction between points becomes blurred; information becomes distributed as in the example of the surface of a pond. What is organism (with its component organs) is no longer sharply distinguished from what lies outside the boundaries of the skin. In the holographic domain, each organism represents in some manner the universe, and each portion of the universe represents in some manner the organisms within it. Earlier in this paper, this was expressed in the statements that the perceptions of an organism could not be understood without an understanding of the nature of the physical universe and that the nature of the physical universe could not be understood without an understanding of the observing perceptual process.

It is, thus, the fact that the holographic domain is reciprocally related to the image/object domain that implies that mental operations (such as mathematics) reflect the basic order of the universe. Of special additional interest is one characteristic of the holographic order. This domain deals with the density of occurrences only; time and space are collapsed in the frequency domain. Therefore the ordinary boundaries of space and time, locations in space and in time become suspended and must be "read out" when transformations into the object/image domain are effected. In the absence of space-time coordinates, the usual causality upon which most scientific explanation depends must also be suspended. Complementarities, synchronicities, symmetries, and dualities must be called upon as explanatory principles.

The answer to the initial question as to whether mind, consciousness and psychological properties in general are emergents or expressions of some basic ordering principle, rests on which of two reciprocally related domains is considered primary, the image/object or the implicate holographic. Scientists are, as yet, only barely

[1] Much of the weekend conference sponsored by The Association for Humanistic Psychology was devoted to presenting this evidence in detail.

acquainted with the implicate order which has, however, apparently been explored experientially by mystics, psychics and others devling into paranormal phenomena. Perhaps if the rules for "tuning in" on the holographic, implicate domain could be made more explicit, we could come to some agreement as to what constitutes the primary basic order of the universe. At the moment this order appears so indistinguishable from the mental operations by which we operate on that universe that we must conclude either that our science is a huge mirage, a construct of the emergent of our convoluted brains, or that, indeed, as proclaimed by all great religious convictions, a unity characterizes this emergent and the basic order of the universe.