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QUANTUM INFORMATION PROCESSING IN BRAIN SYSTEMS AND THE SPIRITUAL NATURE OF MANKIND

By Karl H. Pribram

Extremists

As in every human endeavor various shades of opinion emerge when an issue becomes "hot", fashionable and of general concern. Pronouncements regarding the nature of mind and especially of its conscious aspects are no exception. Daniel Dennet (1991) has humbly contributed a volume entitled 'Consciousness Explained'. In it he replaces the Cartesian theater (Shakespeare's 'Stage'?) with a tentative pluralistic set of narratives recounting our experience. Those of us who are visually and kinesthetically as well as verbally inclined might prefer to stick with Descartes and Shakespeare. Marvin Minsky (1986) has also emphasized the plurality of mental processes in his 'Society of Mind'. My question is: Have these volumes made any significant change in the basic proposition forwarded by Francis Gall at the end of the 18th century that a variety of 'faculties of mind' can be correlated with a corresponding variety of cerebral systems? The details of correspondence, have, of course, been immensely enriched during the ensuing two centuries of research and observation. But, as to philosophy, what is new?

At the other extreme are those who espouse an 'eliminative materialism'. Folk psychology, the wisdom and folly enfolded in language and in cultural expression over the ages, is to be eliminated as scientific explanation in favor of a neural explanation. One is reminded of psychology's era of behaviorism. Stephen Stich has contributed to this endeavor a book entitled 'From Folk Psychology to Cognitive Science' (1986). Its subtitle is "The Case Against Belief". The argument presented in support of this extreme materialism are convoluted but seem to me to ignore the issue of scale or level. How can anyone currently ignore the fact that those who, in the former Yugoslavia as proponents of ethnic cleansing, are operating on any basis other than belief? Only differences between Orthodox, Roman Catholic and Islamic beliefs separate the protagonists. The origins and consequences of these differences in belief can be ascertained and many of them shown to be material in nature. But, just as in the word processing performed by my computer in the writing of this essay, the material instantiations of the cultural history would be as cumbersome to communicate, as would the contents of this essay in machine language. Each level of description has value determined by the use to which the description is to be put.

Scientific Dualisms: Mental and Material

Attention to the levels at which analysis is pursued helps resolve many of the hitherto untractable issues surrounding the mind/brain interface. In the ordinary world of appearances, there is no question but that human mental experiencing can be distinguished sharply from the contents of the experience. The issue has been labeled 'intentionality' (or intentional inexistence) by Franz Clemens Brentano and has given rise to inferences about the nature of reality (Brentano, 1973, Chisholm, 1960). The question is often phrased: Are my perceptions (my phenomenal experiences) the 'real', or do the contents of those perceptions make up the 'real' world? My phenomenal experiences are mental; the world as it appears to me is material. I can give primacy to my experience and become a phenomenologist, or I can give primacy to the contents of the experience and become a materialist. But I can also give primacy to neither and attest to the dual nature of the reality.

Materialism and phenomenology run into difficulty only when each attempts to deny the other. As long as only primacy is at stake, either view can be made consistent. After all, our experiences are primary, and empiricism is not inimical to a real material world. And we do appear to be experiencing something(s), so our experiences may well become organized by those real (material) somethings (See Bunge, 1980, for a persuasive development of this position).

However, by accepting such a moderate position with regard to mind and matter, we immediately come up against a set of dualist problems. Are the contents of perception 'really' organized by the experience of the perceiver? Is that experience in turn organized by brain function, sensory input, and the energies impinging on the senses? Would a complete description of brain function of an organism also be a description of the experience of that organism? If so, are not the material descriptions of brain, senses, and energies sufficient? Or at least do the descriptions of experience add anything to the material descriptions? Cannot the inverse be equally true? What do the descriptions of brain, senses, and energies materially add to what we so richly experience?

I believe that today there are answers to those questions where only a few years ago there were none. These answers come from 'unpacking' conceptual confusions and demonstrating where each conceptualization captures a part of the truthful whole.

A semantic analysis shows that descriptors of brain, senses, and energy sources are derived from an analysis of experience into components. The components are organismic and environmental (biological and physical or social), and each component can be subdivided further into subcomponents until the quantum and nuclear levels of analysis are reached. This procedure of analysis downward in a hierarchy of systems is the ordinary way of descriptive science. Within systems, causes and effects are traced. When discrepancies are found, statistical principles are adduced and probabilities invoked. Scientists have become adept and comfortable with such procedures.

Mental language stems from different considerations. As in the case of descriptive science, mental terms take their origin in experience. Now, however, experience is validated consensually. Experience in one sensory mode is compared with that obtained in another. Then validation proceeds by comparison of one's experience with that of another. A little girl points to a horse. Up to now, her mother has allowed her to say 'cow' whenever any animal is pointed to. But the time has come to be more precise, and the experience of horse becomes validly different from that of a cow. Mental language is derived from such upward validations in a hierarchy of systems.

Elsewhere I detail the differences in scientific approach that this upward or outward look entails (Pribram, 1965). It is certainly not limited to psychology. When Albert Einstein enunciated his special and general theories of relativity, he was looking upward in the set of hierarchically arranged physical systems. The resultant relativistic views are as applicable to mental conceptualizations as they are to physical ones. It is these relativisms that existentialists and phenomenologists constantly struggle to formulate into some coherent principles. My own belief is that they will be successul only to the extent that they develop the techniques of structural analysis (deconstruction). But structured analyses often depend on enactment to clarify the complexities involved. Abhorrent as the computer and other engineering devices may be to philosophers and psychologists of the existential-phenomenal persuasion, these tools may turn out to be of great service to their mode of inquiry.

If the above analysis is correct, then a dualism of sorts can be entertained as valid. First, however, let me provide a cautionary note. This form of dualism is concerned with the everyday domain of appearances--of ordinary experiences. Commencing with such ordinary experiences, two modes of conceptualization have developed. One mode operated downward in a hierarchy of systems, analyzing experience into components and establishing hierarchical and cause-effect relationships between these components. The other operated upward toward other organisms to attain consensual validation of experiences by comparing and sharing them.

Thus two mirror images--two optical isomers, as it were--are constructed from experience: One we call material and the other mental. Just as optical isomers, although they have identical components and arrangement in chemistry have differing biological properties, so the mental and material conceptualizations have different properties even though they initially arise from the self-same experiences.

I suggest that this is the origin of dualism and accounts for it. The duality expressed is of conceptual procedures not of any basic duality in nature. As we will seen there are other dualities that are more basic, but these are not the ones that have become the staple of those arguing for dualism.

Thus, strictly speaking, mentalism and materialism imply each other, because there would be no need for mentalism if there were no materialism. There is no up without a down. Further, Sperry (1980) and Searle (1984) attempted to limit their mentalism to those structures that are organized by and, in turn, organize the brain. But it is not clear whether they would be willing to go to an epistemological limit that holds that mind interacts with the elementary components making up the brain. Intuition regarding biological roots of mentality is certainly accurate. To confuse the analogy of the computer with the historically based homologies that have given rise to psychological processes is akin to calling a whale a fish. By the same token, however, Sperry and Searle are adamantly opposed to an 'independent existence of conscious mind apart from the functioning brain' (Sperry, 1980, p. 195); their mentalism does not stretch to cover the very essence of what motivates mentalism in the hands of those who oppose it to materialism; that is, the primacy and independence of mental structures.

What Computers Can Tell Us

Within the above caveat, let us look at the usefulness for an analysis of the mind/brain connection of computers, programs, and the processing of information in some detail because in many respects these artifacts so clearly portray some of the problems involved in the mind/brain issue. As noted (see e.g. Searle, 1984), the computer is not a brain, but its programs are constructed by people who do have brains. Nonetheless, computers and their programs provide a useful metaphor in the analysis of the mind/brain issue in which the distinction between brain, mind, and spirit can be seen as similar to the distinction between machine (hardware), low-level programs (e.g., operating systems), and high-level programs (e.g., word processing packages). Low-level programs such as machines languages and assemblers are not only idiosyncratic to particular types of computer hardware, but there is also considerable similarity between the logic of these languages and the logic operations of the machines in which they operate. In a similar vein, to some extent perceptual processes can be expected to share some similarity to brain processes. On to other hand, high-level languages such a Fortran, Algol, and Pascal are more universal in their application, and there is less obvious similarity between their implicit logic and the logic of machines. At the highest level, in languages such as English, with which I address my computer in order to use it as a word processor, the relation between the logos of English (word, concept, logic) and that of the machine is still more remote. However, English relates me to a sizable chunk of the human social order. To complete the analogy, humanity's spiritual nature strives to make contact with more encompassing orders whether they be social, physical, cosmological, or symbolic.

Understanding how computer programs are composed also helps to tease apart some of the issues involved in the 'identity' approach in dealing with the mind/brain relationship. Because our introspections provide no apparent connection to the functions of the neural tissues that comprise the brain, it has not been easy to understand what theorists are talking about when they claim that mental and brain processes are identical. Now, because of the computer/program analogy, we can suggest that what is common to a mental operation and the brain 'wetware' in which the operation is realized, is some order that remains invariant across transformations. The terms information (in the brain and cognitive sciences) and structure (in linguistics and in music) are most commonly used to describe such identities across transformations. Order invariance across transformations is not limited to computers and computer programming. In music we recognize a Beethoven sonata or a Berlioz symphony irrespective of whether it is presented to us as a score on sheets of paper, in a live concert, over our high fidelity music system, or even in our automobiles when distorted and muffled by noise and poor reproduction. The information (the form within) and the structure (arrangement) is recognizable in many embodiments. The materials that make the embodiments possible differ considerably from each other, but these differences are not part of the essential property of the musical form. In this sense, the identity approach to the mind/brain relationship, despite the realism of its embodiments, partakes of Platonic universals, that is, ideal orderings that are liable to becoming flawed in their realization.

In the construction of computer languages (by humans) we gain insight into how information or structure is realized in a machine. The essence of biological as well as of computational hierarchies is that higher levels of organization take control over, as well as being controlled by, lower levels. Such reciprocal causation is ubiquitous in living systems: Thus, the level of tissue carbon dioxide not only controls the neural respiratory mechanism but is controlled by it. Discovered originally as a regulatory principle that maintains a constant environment, reciprocal causation is termed homeostasis. Research over the past few decades has established that such (negative) feedback mechanisms are ubiquitous, involving sensory, motor, and all sorts of central processes. When feedback organizations are hooked up into parallel arrays, they become feedforward control mechanisms that operate much as do the words (of bit and byte length) in computer languages (Miller et al., 1960; Pribram, 1971).

Equally important, programming allows an analysis to be made of the evolution of linguistic tools that relate the various levels of programming languages. Digital computers with binary logic require a low-level language (coded in the numerals 0 or 1) that sets a series of binary switches. At the next level, switch settings can be grouped so that binary digits (bits) are converted into a more complex code consisting of bytes, each of which is given an alphanumerical label. Thus, for example, the switch setting 001 becomes 1, the setting 010 becomes 2, and the setting 100 becomes 4.

Given that 000 is 0, there are now eight possible combinations, each of which is an octal byte. This process is repeated at the next level by grouping bytes into recognizable words. Thus 1734 becomes ADD; 2051 becomes SKIP, and so forth. In high-level languages, groups of words are integrated into whole routines that be executed by one command.

It is likely that some type of hierarchical integration is involved in relating mental processes to the brain. Sensory mechanisms transduce patterns of physical energy into patterns of neural energy. Because sensory receptors such as the retina and the cochlea operate in an analog rather than a digital mode, the transduction is considerably more complex than the coding operations described above. Nonetheless, much of neurophysiological investigation is concerned with discovering the correspondence between the pattern of physical input and the pattern of neural response. As more complex inputs are considered, the issue becomes one of comparing the physically determined patterns with subjective experience (psychophysics) and recording the pattern of response of sensory stations in the brain.

These comparisons have shown that a number of transformations occur between sensory receptor surfaces and the brain cortex. The transformations are expressed mathematically as transfer functions. When the transfer functions reflect identical patterns at the input and output of a sensory station, the patterns are considered to be geometrically isomorphic (iso means same; morph means form), that is, of the same form. When the transfer functions are linear (i.e., superposable and invertible, reversible), the patterns are considered to be secondarily or algebraically isomorphic (Shepard & Chipman, 1970). Thus, as in the case of computer programming, levels are due to transformations that progressively alter the form of the pattern while they maintain intact some basic order, an informational structure.

What I propose, therefore, is an isonomic structural 'monism', which states that the truly basic components of the universe are neither material or mental, but neutral to this dichotomy. The dematerialization of energy in modern physics (which I will review in the next section), supports a 'neutral monism' (James, 1909; Russell, 1948). Critical philosophers (e.g. Herbert Feigl, 1960), who were steeped in linguistic analysis, developed a monistic view by suggesting that the 'mental' and 'material' are simply different ways of talking about the same processes. Thus 'mind' and 'brain' come to stand for separate linguistic systems, covering different aspects of a basic commonality. The problem has been to find a neutral language to describe the commonality without being either mental or material in its connotations.

I have taken this 'dual aspects' view a step further by proposing that each aspect not only is characterized linguistically but, in fact, is a separate 'realization' or 'embodiment' (Pribram, 1971). As noted, I have further proposed that what becomes embodied is informational 'structure'. Thus, in essence I have stood the critical philosopher's approach on its head: The enduring 'neutral' component of the universe is informational structure, the negentropic organization of energy. In a sense, this structure can be characterized as linguistic--mathematical, musical, cultural, and so on. Dual aspects become dual realizations --which, in fact, may be multiple--of the fundamental informational structure. Thus, a symphony can be realized in the playing at a concert, in the musical score, on a record or on a tape, and thence through a high-fidelity audio system at home.

Mind and brain stand for two such classes of realization, each achieved, as described earlier, by proceeding in a different direction in the hierarchy of conceptual and realized systems. Both mental phenomena and material objects are realizations and therefore realities. Both classes of reality are constructions from underlying 'structures', which it is the task of science to specify in as neutral a language as possible (neutral, i.e., with respect to connotations that would suggest that the 'structures' belong in one or the other class). I note elsewhere the relationship of such a constructional realism to critical realism, pragmatism, and neo-Kantian rationalism (Pribram, 1971).

There is thus an important difference between a constructional realism such as I propose and materialist, mentalist, dualist, and triadic interactionisms. In a constructional scheme the precise place of brain mechanisms can be specified. There is no global 'mind' that has to make mysterious contact with global 'brain'. Many mysteries are still there-to name only one, for example, how emergents come about and why they are so utterly different from their substrate. But issues become scientific and manageable within the broader context of philosophic enquiry.

The World of Appearance and the World of Potentiality

Holding to structural isonomy (obeying related laws) with regard to the mind/brain issue involves specifying what is the focus of the issue. Unless something remains constant across all the coding operations that convert English to binary machine code and back to English, my word processing procedures would not work. Isonomy implies reciprocal stepwise causation among structural levels. Contrary to the usually held identity position, isonomy does not necessarily mean geometrical or even algebraic isomorphism. Transformations, coding operations, occur that hierarchically relate levels of complexity with one another. A level is defined by the fact that its description, that is, its code, is in some nontrivial sense more efficient (i.e., requires less work, less expenditure of energy) than use of the code of the components that compose it. In the case of the word processor, the coding is arbitrary, and the arbitrariness is stored on a diskette and copy-righted. In the case of the mind/brain relationship, the nature of the coding operations is more universal and the efforts of two centuries of psychophysical, neuropsychological, and cognitive research have provided knowledge concerning at least some of the coding operations involved.

I am belaboring these findings of scientific research to indicate that, contrary to what some philosophers hold (see, e.g. Dewan et al., 1976), they have relevance to philosophical issues. If the mind/brain problem arises from a distinction between the mental and the material and we find that at a certain level of analysis we no longer can clearly make such a separation, then the very assumptions upon which the issue is joined may be found wanting.

Levels of analysis thus concern the fundamental assumption that has given rise to the mind/brain problem: Mental phenomena and the material universe must, in some essential fashion, differ from each other. As we have seen, in the ordinary domain of appearances, at the Euclidean-Newtonian level of analysis, this view is certainly tenable. But at the levels of the macro- and microphysical universes, dualism becomes awkward. Niels Bohr's complementary and Werner Heisenberg's uncertainty principle emphasize the importance of the observer in any understanding of what presumably is observed (Bohr, 1966; Heisenberg, 1959). Eugene P. Wigner (1969) stated the issue succinctly: Modern microphysics and macrophysics no longer deal with relations among observables but only with relations among observations.

An objection can be entered that such difficulties of distinguishing observables from observations encountered today by physicists are temporary, superficial, and of no concern to philosophers interested in the eternal verities. But that is not the message these thoughtful pioneers in physics are attempting to convey. They have been exploring universes where the everyday distinction between material and mental becomes disturbingly untenable at a very fundamental level. As I proceed, I shall tender some explanations that may help account for their views.

The dematerialization of energy can be traced in some sense to earlier formulations. For instance, physics was conceptually understandable in James Clerk Maxwell's day when light waves were propagated in the 'ether'. But then physicists did away with the 'ether'. Still, they did not rid themselves of Maxwell's wave equations or the more recent ones of Erwin Schroedinger (1928) or Louis Victor Prince de Broglie (1964). One readily can conceptualize waves traveling in a medium, such as when sound waves travel in air, but what can be the meaning of light or other electromagnetic waves 'traveling' in a vacuum? Currently physicists are beginning to fill that vacuum with dense concentrations of massless bosons, zero point energy and quantum potential for doing work when interfaced with matter. It is this potential that, I propose, is neutral to the mental-material duality.

In science, such potentials are defined in terms of the actual or possible work that is necessary for realization to occur and are measured as change in terms of energy. Thus, multiple realization imply a neutral monism in which the neutral essence, the potential for realization, is energy. And, as stated in the second law of thermodynamics, energy is entropic, that is, it can have structure. Energy is not material, only transformable into matter. It is measured by the amount of work that can be accomplished by using it and the efficiency of its use depends on its organization as measured by its entropy. The invention of the vacuum tube and subsequent devices have shown that properly configured minute amounts of energy can control large expenditures and that these minute organizations provide 'information', that is, they inform and organize energy. Measures of information and entropy thus were seen as related (see, e.g., Brillouin, 1962; Von Weizsacker, 1974). Computers were constructed to process information, and programs were written to organize the operations of computers. Is the information contained in a program 'material' or 'mental'? If it is either, what then of the information in a book? Or the entropy that describes the behavior of heat engine or of a warm-blooded mammal? Clearly, we have come to the limit of usefulness of a distinction between the material and the mental.

Heisenberg (1959) developed a matrix approach to understanding the organization of energy (and momentum, i.e., inertia). Currently, this approach is used in s-matrix, bootstrap theories of quantum and nuclear physics by Henry Stapp (1965) and Geoffrey Chew (1966). These investigators (among others, Dirac, 1951) have pointed out that measures of energy and momentum are related to measures of location in space-time by way of a Fourier transform. The Fourier theorem states that any pattern of organization can be analyzed into, and represented by a series of regular waveforms of different amplitudes and frequencies and phase relations. These regular waveforms can in turn be superimposed, convolved, with one another and, by way of the inverse Fourier procedure, can be retransformed to obtain correlations in the original space-time configuration. Thus, the Fourier transform of a set of patterns displays a spectral organization that is, of course, different from that which is displayed after the inverse Fourier transform has again converted the pattern into the spacetime order.

In terms of the proposition put forward by Dirac, Stapp and Chew, this means that the organization of energy and momentum is considerably different from the space-time organization of our ordinary perceptions that can be expressed in Euclidean, Cartesian, and Newtonian terms. David Bohm (1971, 1973, 1976) has identified these nonclassical organizations of energy potentials as 'implicate', that is, enfolded, and has used the hologram as an example of one such enfolded order. Because Bohm has concerned himself with additional unspecified implications, I will refer to this as a first implicate or implex order. Dennis Gabor (1946, 1948), the inventor of the hologram, based his discovery on the fact that one can store on a photographic film, interference patterns of waveforms produced by the reflection or refraction of light from an object and reconstruct from such a film the image of the object. It is probably no accident that holograms were a mathematical invention (by Dennis Gabor) that used a form of mathematics the integral calculus, invented by Gottfried Wilhelm Leibniz, who also came to a vision of the implex order. Leibniz's monadology (1714/1951) is holographic; his monads are distributed, windowless forms each of which is representative of the whole. Substitute the term lensless for windowless, and the description of a monad and a hologram is identical. Today the description of the enfolded organization of the stored potential for reconstruction is related to the unfolded space-time description of the object by a Fourier transform.

The Fourier theorem has also played an important role in the recent discoveries in the brain sciences. In the late 1960s, several groups of investigators found that they could explain their findings in visual research when they realized that their results indicated that encoding of spatial patterns in the visual system involved what they called spatial frequency. This term describes the spectral domain that results when a Fourier transform is performed on space-time. Fergus Campbell an John Robson (1968) of Cambridge University discovered unexpected regularities in their data: Responses to gratings of different widths and spacings adapted not only to the particular grating shown but also at other data points. These additional adaptations could be understood by describing the gratings as composed of regular waveforms with a given frequency and the regularities in terms of harmonics. The spectral frequency was determined by the spacings of the grating, and thus the term spatial frequency. Spatial and temporal frequencies are related of course: Scanning by a steadily moving beam would describe the grating's temporal frequency. Physicists therefore use the term wave number to denote the purely frequency, spectral form of description of patterns.

What this means is that the optical image is decomposed into its Fourier components: regular waveforms of different frequencies and amplitudes. Cells in the visual system respond to one or another of these components and thus, in aggregate, comprise an image processing filter or resonator that has characteristics similar to the photographic filter comprising a hologram, from which images can be reconstructed by implementing the inverse transform.

There are, however, important differences between ordinary photographic holograms and the visual nervous system. Ordinary holograms are composed by a global Fourier transform that distributes the information contained in a space-time image throughout the transform domain. In the visual nervous system, distribution is limited anatomically to the input channeled to a particular cortical cell. Nonetheless, there are holographic techniques that use similar 'patch' or multiplex constructions. Bracewell (1965) at Stanford University pioneered these techniques in radioastronomy by stripping together the holographic transformations of limited sectors of the heavens as viewed by radiotelescope. When the inverse transform is applied, space-time images of the whole composite can be viewed in three dimensions.

Furthermore, the transorm that best describes the process in the visual system is a Gabor, not a Fourier. The Gabor transform (Gabor 1946, 1948; Pribram and Carlton, 1987; Daugman, 1985; Marcelja, 1980) is formed by placing a Gaussian envelope on the otherwise unlimited Fourier transform. This is another way of stating that the transformation is patchlike and not global, and gives mathematical precision to the limits involved.

Finally, the arrangement of the visual channels and the cortical cells is not haphazard with regard to one another. A clear retinotopic to cortical spatial arrangement is maintained. Thus the gross grain of the visual filter determines space-time coordinates, whereas its fine-grain describes the Fourier components.

What advantage is gained by this fine-grain holographic-like organization? Recall that in the transform domain correlations among patterns are readily performed. This is why the Fast Fourier Transform (FFI) as performed by computer is such a powerful tool in statistical analysis and in computerized tomography (CT scans). The brain is an excellent correlator by virtue of its finegrain processing potential.

The dual properties of an enfolded fine-grain (technically, the synaptodentritic receptive field organization) and a gross-grain space-time organization applies to other sense modalities as well, although the experimental evidence is not as complete. Georg von Bekesy (1967) performed critical studies in the auditory and someasthetic modalities, Walter Freeman (1960) conducted studies in the olfactory, King, Xie, Zheng and Pribram (1994) in the somatosensory, and Pribram, Sharafat, and Beekman (1984) have shown that cells in the sensorimotor cortex are tuned to specific frequencies of movement. At the same time, in all these sensory systems the spatial organization of the receptor surface is topographically represented in the gross-grain arrangement of the cortical cells that receive the sensory input.

In summary, there is good evidence that another class of orders lies behind the ordinary classical level of organization we ordinarily preceive and which can be described in Euclidean and Newtonian terms and mapped in Cartesian space-time coordinates. The other class of orders is constituted of fine-grain distributed organizations described as potential because of the radical changes that occur in the transformational process of realization. When a potential is realized, information (the form within) becomes unfolded into its ordinary space-time appearance; in the other direction, the transformation enfolds and distributes the information as this is done by the holographic process. Because work is involved in transforming, descriptions in terms of energy are suitable, and as the structure of information is what is transformed, descriptions in terms of entropy (and negentropy) are also suitable. Thus on the one hand there are enfolded potential orders, on the other there are unfolded orders manifested in space-time.

The point was made earlier in this essay that the dualism of mental versus material holds only for the ordinary world of appearances-the world described in Euclidean geometry and Newtonian mechanics. An explanation of dualism was given in terms of procedural difference in approaching the hierarchy of systems that can be discerned in this world of appearances. This explanation was developed into a theory, a constructional realism. But it was also stated that certain questions raised by a more classical dualistic position were left unanswered by the explanations given in terms of an identity position.

Two issues can be discerned: 1) What is it that remains identical in the various levels of the hierarchy of programs of compositions? and 2) Is the correspondence between machine language (program or musical notation) and the machine or instrument's operation an identity or a duality? I believe the answer to both the questions hinges on whether one concentrates on the order (form, organization) or the embodiments in which these orders become instantiated (Pribram, 1986; 1993).

There is a difference between surface structures of different grains which become trans-formed and the deeper isonomy which in-forms the transformations. Transformations are necessary to material and mental 'instantiations' -- Plato's particular appearances -- of the ideal in-forms: the instantiation of Beethoven's 9th Symphony is transformed from composition (a mental operation) to score (a material embodiment) to performance (more mental than material) to recording on compact disc (more material than mental) to the sensory and brain processes (material) that make for appreciative listening (mental). But the symphony as symphony remains recognizable as Beethoven's creative composition over the centuries of performances, recordings and listenings.

Instantiations depend on transformations among orders. What remains invariant across all instantiations is 'in-formation', the form within. Surprisingly, according to this analysis, it is a Platonic 'idealism' that motivates the information revolution ('information processing' approaches in cognitive science) and distinguishes it from the materialism of the industrial revolution. Further, as in-formation is neither material nor mental, a scientific pragmatism akin to that practiced by Pythagoreans, displaces mentalism and dualism as well as materialism. At a minimum the tension between idealism (the potential), and realism (the appearance) which characterized the dialogue between Plato and Aristotle, will replace that between mentalism and materialism.

REFERENCES

Bekesy Von., G. (1967). Sensory inhibition. Princeton, N.J: Princeton University Press.

Bohm, D. (1971). Quantum theory as an indication of a new order in physics. Part A. The development of new orders as shown through the history of physics. Foundation of Physics, 1, pp. 359-381.

Bohm, D. (1973). Quantum theory as an indication of a new order in physics. Part B. Implicate and explicate order in physical law. Foundations of Physics, 3, pp. 139-168.

Bohm, D. (1976). Fragmentation and wholenest. Jerusalem: VanLeer Jerusalem Foundation.

Bohr, N. (1966). Atomic physics and human knowledge. New York: Vintage.

Bracewell, R.N. (1965). The Fourier transform and its application. New York: McGraw-Hill.

Brillouin, L. (1962). Science and information theory (2nd ed.). New York: Academic Press.

Brentano, F. (1973). Psychology from an empirical standpoint (A.C. Rancmello, D.B. Terrell, & L.L. McAlister, Trans.). London: Routledge & Kegan Paul.

Bunge,M. (1980). The mind-body problem. Oxford, England: Pergamon Press.

Campbell, F.W. & Robson, J.G. (1968). Application of Fourier analysis to the visibility of gratings. Journal of Physiology, 197, pp. 551-566.

Chew, G.S. (1966). The analytic s-matrix. A basis for nuclear democracy. New York: Benjamin.

Chisholm, R.M. (1960). Realism and the background of phenomenology. New York: Free Press.

Daugman, J.G. (1985, July). Uncertainty relation for resolution in space, spatial frequency, and orientation optimized by two dimensional visual cortical filters. Journal of the Optical Society of America, 2 (7), pp. 1160-1169.

Dennet, Daniel C. (1991). Consciousness Explained. Boston: Little Brown & Co., (p.511).

Descartes, R. (1927). Selections. New York: Scribner.

Dewan, E.M., Eccles, J.C., Globus, G.G., Gunderson, K., Knapp, P.H., Maxwell, G. , Pribram, K.H., Savage, C.W., Savodnik, I., Scriven, M., Sperry, R.W., Weimer, W.B., Wimsatt, W.C. (1976). The role of scientific results in theories of mind and brain: A conversation among philosophers and scientists. In G.G. Globus & G. Maxwell (Eds.) Consciousness and the brain (pp. 317-328). New York: Plenum Press.

Dirac, P.A.M. (1951). Is there an aether? Nature, 168,906.

Feigl, H. (1960). Mind-body, not a pseudoproblem. In S. Hook (Ed.), Dimensions of mind (pp. 33-44). New York: Collier.

Freeman, W.J. (1960). Correlation of electrical activity of prepyriform cortex and behavior in cat. Journal of Neurophysiology, 23, pp. 111-131.

Gabor, D. (1946). Theory of communication. Institute of Electrical Engineers, 93: pp.429-441.

Gabor, D. (1948). A new microscopic principle. Nature, 161, pp. 777-778.

Heisenberg, W. (1959). Physics and philosophy. London: Allen & Unwin.James, W. (1909). A pluralistic universe. London: Longman's, Green & Co.

King, J.S., Xie, M., Zheng, B., & Pribram, K.H. (1994). Spectral Density Maps of Receptive Fields in the Rat's Somatosensory Cortex. In Pribram, K.H. (Ed.) Origins: Brain & Self Organization. New Jersey: Lawrence Erlbaum Associates, pp. 556-571.

Leibniz, G.W. (1951). The Monadology and other philosophical writings. London, England: Oxford University Press. (Original work published 1714).

Marcelja, S. (1980). Mathematical description of the responses of simple cortical cells. Journal of the Optical Society of America, 70, pp. 1297-1300.

Miller, G.A., Galanter, A., & Pribram, K.H. (1960). Plans and the structure of behavior. New York Henry Holt & Company.

Minsky, Marvin. (1986). Society of Mind. New York: Simon & Schuster.

Pribram, K.H. (1965). Proposal for a structural pragmatism: Some neuropsychological considerations of problems in phylosophy. In B. Wolman & E. Nagle (Eds.), Scientific of psychology: Principles and approaches (pp. 426-459). New York: Basic Books.

Pribram, K.H. (1971). Languages of the Brain: Experimental paradoxes and principles of neuropsychology. Englewood Cliffs, NJ: Prentice-Hall; Monterey CA: Brooks/Cole, 1977; New York: Brandon House, 1982. (Translations in Russian, Japanese, Italian, Spanish).

Pribram, K.H. (1986). The cognitive revolution and mind/brain issues. American Psychologist, 417, pp. 507-520.

Pribram, K.H. (1993). Afterword. In K.H. Pribram (Ed.), Rethinking Neural Networks: Quantum Fields and Biological Data (pp. 531-536). New Jersey: Lawrence Erlbaum Associates, Inc.

Pribram, K.H. & Carlton, E.H. (1987). Holonomic brain theory in imaging and object perception. Acta Psychologica, 63, pp. 175-210.

Pribram, K.H. Sharafat, A. Beekman, G.J. (1984). Frequency encoding in motor systems. In H.T.A. Whiting (Ed.), Human motor actions: Bernstein reassessed (pp. 121-156). Amsterdam: North-Holland/elsevier.

de Broglie, LV. Prince (1964). The current of wave mechanisms: A critical study. (Express Transaction Service, Trans.) Amsterdam: Elsevier.

Russell, B. (1948). Human knowledge, its scope and limits. New York: Simon & Schuster.

Schroedinger, E. (1928). Quantization as a problem of proper values. In J.F. Shearer & W.M. Deans (Eds.), Collected papers on wave mechanics. London: Blackie.

Searle, J.R. (1984). Minds, brains and science. Cambridge, MA: Havard University Press.

Shepard, R.N. & Chipman, S. (1970). Second-order isomorphism of internatl representations: Shapes of States. Cognitive Psychology, I, pp. 1-17.

Sperry, R.W. (1980). Mind/brain interaction-Mentalism, yes-Dualism, no-Neuroscience, Z pp. 195-206.

Stapp, H.P. (1965). Space and time in s-matrix theory. Physiological Review, 135B, pp. 257-270.

Stich, Stephen P. (1986). From Folk Psychology to Cognitive Science- The case against belief. Cambridge, MA: A Bradford Book, MIT Press.

Weizsacker, E. von (1974). Official systems I. Stuttgart, FRG: Verlag.

Wigner, E.P. (1969). Epistemology of quantum mechanics: Its appraisals and demands. In M. Grene (Ed.), Tize anatomy of knowledge (pp. 31-45). London: Routledge & Kegan.