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The Cognitive Revolution and Mind/Brain Issues

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ABSTRACT: The advent of the cognitive revolution made mind respectable in psychology once more. Simultaneously a surge of data in the neuro- and computer sciences began to converge on psychological issues such as the nature of perception and the mechanisms of memory. Thus, we are currently faced with a resurgence of interest in the mind/brain relationship. The time is ripe to address this relationship in terms of scientific theory based on, but not limited to, philosophical inquiry. Each of the proposed stances in philosophy must be examined not only in terms of logic but also by identifying the database to which the stance refers. The philosophical positions on the mind/brain relationship such as identity, dualism, interactionism, materialism, physicalism, and mentalism each have grounds that appear instructive and irrefutable when limited to a restricted database. As such, they can be considered theories. But these theories cannot be extended beyond their databases into overarching cosmologies. Unpacking the mind/brain issues in this manner reveals, on the one hand, an epistemological pluralism and, on the other, that concepts such as information, entropy, and energy are neutral to the mind/brain dichotomy. These concepts constitute the ground for a "neutral monism" that can be conceived of as a potentiality and thus ontologically prior to, but not epistemologically encompassing, the relationship between mind and brain.

Interest in the relationship between mind and brain has become invigorated by the surge of activity in the neurosciences and in what has come to be called "cognitive science." The time is therefore ripe to take a new look at this age-old problem, but now from the standpoint of the scientist as well as from that of the philosopher. Today, we are in a position not only to reevaluate major philosophical stances but also to develop more limited and precise theories and models of mind/brain relationships that subsume a restricted database.

The surge of interest in mind/brain issues has come in various guises. Cognitive scientists have argued whether "representations" or "computations" characterize the relationship (see, e.g., Gardner, 1985; "Special Issue" in *The Behavioral and Brain Sciences*, 1980). A philosopher and a neuroscientist have banded together only to find themselves maintaining an interactive separateness of mind and brain (Popper & Eccles, 1977). And a neuroscientist (Sperry, 1952, 1969, 1976), as well as a philosopher (Searle, 1979) have declared themselves solidly on the side of mind (Sperry, 1980), whereas a psychologist (Skinner, 1971, 1976) has given up hope that a "science of mental life" as William James (1901), and more recently George Miller (1962), have dubbed it, is possible at all because such a science would depend on verbal communications, which are notoriously ambiguous.

It is this variety in the attempts to deal with mind/brain relations that calls forth my reevaluation. I know most of the protagonists personally and have high regard for all of them, as I have for much of the philosophical discourse that bears on the issues. It seems to me that these intelligent scholars cannot all be wrong despite the fact that their respective contributions are at variance with one another. Could it then be that they are all correct, in some nontrivial sense? If so, how?

My suggestion, to be developed here, is that each of these espoused philosophical positions has captured a part of the domain of issues and that what is necessary is to determine the database on which the position rests. The failure of philosophy to resolve the issues comes when a position is maintained beyond the confines of its relevant database to a point where another position is more appropriate.

The danger of such an eclectic approach is that one may end up with an "any worlds" or at least with a "many worlds" relativist viewpoint, which is fine if one wishes to show merely that there are many different answers to the questions posed. But I am not satisfied with such a result. I hope to be able to show that the several databased theoretical frames fit different agendas in philosophy and that a unified view can be constructed out of the diversity of theories.

I will provide one caveat: The approach taken here is new and must therefore of necessity be inadequate and even "wrong" in detail. The important consideration is that the approach is a viable one and that it can be progressively sharpened by recourse to experimental disconfirmation (see Popper, 1968a, 1968b). The approach is essentially scientific but heeds the questions so carefully honed by philosophical inquiry.

The approach taken here leads to some apparent paradoxes: Dualism, pluralism, monism, constructivism, realism, and even idealism all find a place in the metaphysical scheme. Inferences from reaction time data, recordings of event-related brain potentials, and other results of experimental observations have led to the acceptance of the idea that cognitive operations are taking place in the brains of sensing and behaving organisms. As I hope to make clear, this epistemological acceptance leads to a pluralistic realism that is comfortable with dualism at the ordinary level experienced by behaving organisms.

In contrast, the reliance of cognitive science on computers and programs and of neuroscience on "information processing" interpretations, is constructivist and

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leads us close to idealism: an "informational" monism as seen from the identity vantage. Codes and transforms are shown to be the vehicles by means of which informational structures remain invariant over a variety of embodiments, a variety of realizations.

Finally, an ontological neutral origin is shown to resolve the apparent paradox of invariance of informational structure and a plurality of realities. It is shown that to identify invariance solely as mental leads to awkward interpretations such as those that would hold that computers have "minds" and "feelings." Instead, a plausible case is made that what remains invariant across transformations is neutral to the mind/brain, mental–material duality and is captured by physicists' definitions of energy and the amount of its structure: entropy, and its converse, negentropy (i.e., information). Such information can be realized mentally as well as materially, an idea captured by the aphorism that, on occasion, the pen can be mightier than the sword.

Metaphysics

Some Recent History

The story of current thinking on the mind/brain issue begins with Ernst Mach (1914) and the positivist approach. Mach was a dualist and a parallelist; mind and brain for him had identical structures but were forever separate entities. Mach's position gave rise to two major approaches, each centered on a particular problem. The first of these approaches accepted Mach's dualism but noted that mind and brain do interact, that is, influence each other. The question arose as to how that interaction might take place. Popper and Eccles (1977) answered this question by suggesting that mental processes create a "World 3" of language and culture that in turn feeds back, through the senses, to influence brain mechanisms. Mind itself was noted to be an emergent of this interaction, an emergent immersed in the sensory (and motor) processes that relate the brain to the organism's environment.

The Vienna Circle, and especially Feigl (1960), addressed a different problem in Mach's formulation. If indeed identical structures characterize brain and mind, what is it that is structurally identical? Feigl, in keeping with positivist tradition, focused on language and suggested that mind talk and brain talk were different aspects of some underlying Machian structure. In his identity theory, Feigl gave up dualism and opted for the monistic emphasis on basic structure.

Both Popper's and Feigl's programs have much merit, but each also poses new questions, questions that can lead to further insights. Just what is it that makes up World 3? What is the essence of language and culture that can so readily influence the brain? In the multiple aspects view, what is it that the aspects refer to? My answer to these questions is presented in scientific rather than philosophical terms. By this I mean that I am to identify the data set that each of the philosophic programs addresses rather than to push each program to its logical limit. The result of this approach is a neutral monism, neutral to the mind/brain duality, with the potential for multiple realizations. Feigl's linguistic dual aspects (e.g., mind talk and brain talk) are replaced by a plurality of realizations. A new duality is discovered: the duality between potential orders and their realizations.

Behavior and Experience

In contrast to philosophers, psychologists, under the banner of a realist radical behaviorism, eschewed any scientific reference to mind. As noted, the reasons for this are not arbitrary. Rather, as both Skinner (1971, 1976) and Quine (1960) have pointed out, the issue is that no two people mean exactly the same thing when they use a particular word or phrase. Furthermore, we can never be sure that even when we use a word such as *green* that it denotes the same experience to each person using it. But this is an issue common to all of science and indeed to all cognition, as Berkeley (1904) so persuasively argued. Are we therefore to give up, hang our heads, and sit in isolation in our respective existential corners? Of course not. Nor does it mean that in constructing a science we *must* exclude reference to our conscious experience. A common alternative is to make inferences and to proceed to deal with them. Cognitive science can and does proceed in just this fashion (see, e.g., Johnson-Laird & Johnson-Laird, 1983).

The issue is not just a philosophical one. When patients with occipital lobectomies say that they are blind even though they are able to respond correctly to the location and configuration of visual cues (Weiskrantz, 1974; Weiskrantz, Warrington, Sanders, & Marshall, 1974), how are we to deal with their "blind-sight" except to distinguish their instrumental responses from their verbal reports of introspection? A radical behaviorist would want to discount the introspective report as not "real"; in fact, several died-in-the-wool behaviorists have told me that they are certain that either the patients or the experimenters were lying. But this type of patient is not unique. Brenda Milner's (1966) famous subject, H.M., who had sustained a bilateral medial temporal lobe resection, has a similar difficulty: He cannot consciously remember Brenda even after some 30 years of repeated testing while at the same time he performs perfectly in an operant situation that he learned many months before (Sidman, Stoddard, & Mohr, 1968).

The alternative is to ascertain to the best of our ability that we can accept at face value both the instrumental behavior and the verbal report and to go about the search for the neural mechanism that, when injured, can account for the dissociation. We accept the inference that the subject has a "mental life," that his or her psychological processes are accessible by way of his or her verbal reports

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and instrumental behaviors, and furthermore, that these different forms of behavior may reflect different processes.

Philosophers and psychologists of a nonbehaviorist persuasion may counter that any argument about mental phenomena derived from behavior is spurious. They would rather begin with "the phenomenon itself existentially experienced." But there is little that can be done with such experiences except to attempt to describe them (behaviorally) and to organize the descriptions (structurally). Thus, Maurice Merleau-Ponty (1963), an existentialist philosopher, has authored a book entitled *The Structure of Behavior*, which in both spirit and content shows remarkable resemblances to our own *Plans and the Structure of Behavior* (Miller, Galanter, & Pribram, 1960; see also Pribram, 1965), which tackles the issues from a behavioral and information-processing vantage. I do not mean to convey here that there is no distinction between a behavioristic and an existential–phenomenalistic approach to mind. Elsewhere I detail this distinction in terms of a search for causes by behaviorists and a search for informational structure reasonably (meaningfully) composed by phenomenologists (Pribram, 1979). What I do want to emphasize here is that both approaches lead to conceptualizations that cannot be classified readily as either mental or material. In their search for causes, behaviorists rely on drives, incentives, reinforcers, and other "force-like" concepts that deliberately have a Newtonian ring. In their quest for understanding mental experience, existentialists come up with structure much as do anthropologists and linguists when they are tackling other complex organizations. And structural concepts are akin to those of modern physics where particles arise from the interactions and relationships among processes. The view to be developed here is that in neither case can this resultant of inquiry be characterized as mental or material unless one wishes simply to state a bias in favor of one or the other as being more meaningful to oneself.

Hierarchy, Reciprocal Causation, and Mind/Brain Identity

Let us look at this issue of structure in terms 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 has been repeatedly 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 programs). Low-level programs such as machine 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 the other hand, high-level languages such as 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 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 mental operations 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, and even in our automobiles when distorted and muffled by noise and poor reproduction. The information (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, 1971a).

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 the 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 can 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 patterns 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. These 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 of processing are recognized, each cascade in the level producing transformations that progressively alter the form of the pattern while maintaining intact some basic order, an informational structure.

In short, holding the identity "position" with regard to the mind/brain issue involves specifying what it is that remains identical. Unless something remains constant across all of the coding operations that convert English to binary machine code and back to English, my word processing procedures would not work. Identity implies reciprocal stepwise causation among structural levels. Contrary to the usually held philosophical position, identity 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 copyrighted. In the case of the mind/brain relationship, the nature of the coding operations is more universal and the efforts of a century and a half 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.

Within the framework of these considerations, let us now look at some specific dualistic and mentalistic proposals that have been forwarded recently and place them within a perspective that states that the material-mental dichotomy holds only for the ordinary Euclidean-Newtonian world of appearances.

Do Experiences Matter or Does Matter Become Experienced?

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 does the content 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 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?

Epistemology

Transcending Dualisms Without Denying Them

I believe that today there are answers to these 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 a 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 successful only to the extent that they develop the techniques of structural analysis. 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 operates downward in a hierarchy of systems, analyzing experience into components and establishing hierarchical and cause–effect relationships between these components. The other operates 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 in chemistry have differing biological properties, although they have identical components and arrangements, so the mental and material conceptualizations have different properties even though they initially arise from the selfsame 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 see, there are other dualities that are more basic, but these are not the ones that have become the staple of those arguing for dualism.

Mind as Emergent and as Actor

The views expressed thus far have provided a coherent theory that accounts for dualistic views but transcends them by showing them to arise from procedural differences that separately realize a common structure. That structure is neutrally described in mathematical and information-processing (or similar) terms—terms that cannot readily be characterized as either material or mental.

This theory is considerably different from more classical dualistic views that hold to a fundamental separation between the mental and material. This separation has also been ameliorated recently by the proposal (Popper & Eccles, 1977) that interaction between the mental and material takes place by way of a material-like cultural domain that feeds back through the material senses to the material brain. Mental processes are then the emergents that result from this interaction. However, I have argued elsewhere that the way Popper—and Eccles—defined mind in terms of such interactions is akin to a colloquial use of the concept "force" (Pribram, 1976). We say, for instance, that gravitational force, "gravity," pulls us to the earth. However, the concept of gravity was derived from studying the interactions of masses in motion. Gravity is thus by definition an interaction term; gravity would not "exist" were there no "us" to be attracted to the earth (and other bodies). We would reify gravity and have it pull us; and appearances certainly confirm this way of conceiving forces: that they are being "produced" by one body and operating on another. Popper developed his thesis of World 3 being "produced" by World 2 in this spirit.

What I see as helpful in the World 2–World 3 division is the attempt to portray the same issue that I discuss in terms of structure and its realization. In a sense, what I call "structure" is what Popper and Eccles called "mind." The difference is, however, that my "structures," also derived from sensory and behavioral interactions, are realized in material, physical environments (such as the structure of a symphony being embodied in a printed score or a magnetic tape). If these structures are to be identified as mental, my formulation would be akin to those of Alfred North Whitehead (1925), Roger Sperry (1980), John Searle (1983), and Eugene Wigner (1969)—a form of mentalism. But, I am not willing to go that far. Rather, I prefer to hold the line by stating that structures transcend both the physical and mental realities in which they become realized.

As noted, strictly speaking mentalism per se implies dualism because there is no need for mentalism if there were no materialism. There is no up without a down. Further, Sperry and Searle 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 the epistemological limit that holds that mind interacts with the elementary components making up the brain. Intuition regarding the 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.

Constructional Realism: A Pluralistic Monism

Before I proceed with a precise delineation of the experimental and theoretical basis for the approach taken here, it may be helpful to summarize what has been proposed thus far: a "monism," which states simply that the truly basic components of the universe are neither material nor mental, but neutral. The dematerialization of matter at the level of analysis that concerns modern physics (which I will review later in this article) supports such a "neutral monism" (James, 1909; Russell, 1948). Critical philosophers (e.g., Herbert Feigl, 1960), who were steeped in linguistic analysis, developed this 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, 1971b). 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—or 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, 1971a).

There is thus an important difference between a constructional realism such as I propose and mentalist, dualist, and triadic interactionisms. In a constructional scheme the precise place of brain mechanisms can be specified. The sensory and brain perceptual mechanisms that are used to construct the Newtonian reality of appearances; the cognitive, "intrinsic" (my term for Eccles's "liaison") brain mechanisms that are necessary to the formulation of quantum and nuclear physics; the conative, motor brain mechanisms that organize intention and plan; the emergence of feelings from the neurochemical organizations of the brain—all can be fitted into their precise and proper place in the scheme. 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 Neural Microstructure

One example is in the order of such manageability and the precision with which the problems can be stated. I take this example from my own work because Eccles reviewed it and criticized it in his part of the book, *The Self and Its Brain* (Popper & Eccles, 1977). The problem relates to both perception and memory. The issue is how sensory input becomes encoded in the brain cortex. Eccles put the problem in the following way:

> What neural events are in liaison with the self-conscious mind both for giving and receiving. . . . We reject the hypothesis that the agent is the field potential generated by the neural events. The original postulate of the gestalt school was based on finding that a massive visual input such as a large illuminated circle resulted in some topologically equivalent potential field in the visual cortex, even a closed loop! This crude hypothesis need not be further considered. However a more refined version has recently been proposed by Pribram (1971a) in his postulate of micro-potential fields. It is assumed that these fields provide a more subtle cortical response than the impulse generation by neurones. However, this field potential theory involves a tremendous loss of information because hundreds of thousands of neurones would be contributing to a micropotential field across a small zone of the cerebral cortex. All the finer grain of neuronal activity would be lost in this most inefficient task of generating a minute electrical potential by current flow in the ohmic resistance provided by the extracellular medium. In addition we have the further problem that there would have to be some homunculus to read out the potentials in all their patterned array! The assumed feedback from micro-potential fields onto the firing frequencies of neurones would be of negligible influence because the currents would be extremely small.
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> We must believe that there is an essential functional meaning in all the discrete neuronal interactions in spatiotemporal patterns, otherwise there would be a great loss of information. In this context, we must consider the organization of the cortical neurones in the anatomical and physiological entity that is called a module. . . . In the first place it is inconceivable that the self-conscious mind is in liaison with single nerve cells or single nerve fibers. These neuronal units as individuals are far too unreliable and ineffective. In our present understanding of the mode of operation of neural machinery we emphasize ensembles of neurones (many hundreds) acting in some collusive patterned array. Only in such assemblages can there be reliability and effectiveness. . . . the modules of the cerebral cortex . . . are such ensembles of neurones. The module has to some degree a collective life of its own with as many as 10,000 neurones of diverse types and with a functional arrangement of feed-forward and feedback excitation and inhibition. As yet we have little knowledge of the inner dynamic of life of a module, but we may conjecture that, with its complexly organized and intensely active properties, it could be a component of the physical world (World 1) that is open to the self-conscious mind (World 2) both for receiving from and for giving to. We can further propose that not all modules in the cerebral cortex have this transcendent property of being "open" to World 2, and thus being the World 1 components of the interface. By definition there would be restriction to the modules of the liaison brain, and only then when they are in the correct level of activity. Each module may be likened to a radio transmitter-receiver unit. . . . the module may be thought of as an integrated microcircuit of electronics, only vastly more complicated. (Popper & Eccles, 1977, pp. 365–366)

Although Eccles quoted my book *Languages of the Brain: Experimental Paradoxes and Principles in Neuropsychology* (Pribram, 1971a), he ignored in the above account whole sections (e.g., pp. 126–131, 324–327) devoted to what I labeled "logic modules" (Pribram, 1971a). The structure of such modules is presented in much greater detail than Eccles has done in *The Self and Its Brain* or anywhere else. Furthermore, the precise operation of the modules has been simulated by computer on several occasions in my laboratory (Bridgeman, 1971; Phelps, 1974; Pribram, Nuwer, & Baron, 1974; Spinelli, 1966).

But there is more. Eccles criticized me in the first paragraph quoted earlier: "The assumed feedback from micropotential fields onto the firing frequencies of neurones would be of negligible influence because the currents would be extremely small." However, further on he used these same currents (which, as clearly defined in *Languages of the Brain*, are the depolarizations and especially the hyperpolarizations that occur at synapses and within dendritic fields) to "emphasize ensembles of neurones (many hundreds) acting in some collusive patterned array . . . . with as many as 10,000 neurones of diverse types and with a functional arrangement of feed-forward and feedback excitation and inhibition." Excitation and inhibition for the most part are carried out in axonless (Golgi type 2) "local circuit" neurons that depend on the very micropotentials that Eccles criticized in the first paragraph (Rakic, 1976). It is becoming clearer that processing in the brain—processing within local neuronal circuits—is proceeding by way of local electrotonic and chemical communications that characterize dendrodendritic interactions rather than via the action potential mode so characteristic of long sensory and motor pathways (see, e.g., Schmitt, Dev, & Smith, 1976).

G. M. Shepherd and W. Rall have presented voluminous neurophysiological evidence on the functional organization of these local microcircuits—evidence on which I based by proposal of microstructures (Rall, 1970; Shepherd, 1976). What then is the actual difference between Eccles's microcircuits and my microstructures except that I clearly specify the graded response characteristics of the patterning of electrical potentials that produces the functional arrangements within microstructures (or microcircuits) whereas Eccles failed to do so and took umbrage at the self and its mind operating a "radio transmitter-receiver" (the brain modules).

So much for the neurophysiology. The question is of course: What does this neurophysiology gain us with respect to the mind–body problem? I have suggested that the neuronal microstructure, the microcircuitry, is encoding periodic activity and that sensory transduction of environmental energy results in patterns of neuronal activation in the spectral domain. Eccles was not averse to this when he suggested that microcircuits act much as radio transmitters-receivers. Radios operate on periodic information; they are tuned to transmit and receive spectral codes.

The initial evidence for neural encoding in the spectral domain was presented in *Languages of the Brain* (Pribram, 1971a, chap. 8). Since its publication, evidence continues to pour in. Originally, G. S. Ohm and Hermann von Helmholtz suggested that the auditory system operates as a spectral analyzer (Helmholtz, 1863; Ohm, 1843). Georg von Bekesy (1957) showed that the skin and the somatosensory mechanism behave in a similar fashion. But the most dramatic evidence concerns the visual system. More and more evidence is accumulating to show that visual-spatial processing is accomplished in the spectral domain. The visual system analyzes the periodic fluctuations of the intensity of light over space (Campbell & Robson, 1968; DeValois, Albrecht, & Thorell, 1978a, 1978b; Movshon, Thompson, & Tolhurst, 1978a, 1978b, 1978c; Pribram, Lassonde, & Ptito, 1981).

In the engineering sciences, such processing in the spectral domain is called optical information processing (if done with lens systems) or image processing (if performed with computers) or holography (if storage on photographic film is employed). It is holography that first called my attention to the attributes of the spectral domain and their relevance for understanding the mind/brain (Pribram, 1966). In a hologram (the photographic film that stores the microstructure of periodic changes of light and dark over space) the information about forms in space becomes distributed. This sheds light on one of the most difficult problems of neuroscience, namely, how to explain the fact that local lesions in the brain do not selectively impair one or another memory trace. In a hologram, restricted damage does not disrupt the stored information because it has become distributed.

In essence, the information becomes blurred over the entire extent of the holographic film but in such a precise fashion that it can be deblurred by performing the inverse procedure. Thus, image reconstruction (or construction) from the stored spectral domain is simple; applying the same transform that produced the store will also decode it into an image. In short, contrary to what Eccles stated to be a problem with my theory, the evidence that the brain encodes information in the spectral domain indicates that no "homunculus" is needed to read out the memory trace. Either an input from the senses or from some central source (such as Popper's suggestion that the pain-pleasure expectation and attention mechanisms might be responsible; see also Pribram & McGuinness, 1975) will activate the spectrally encoded memory trace to produce an image. No "self-conscious mind" is sitting there, biasing the functions of the association cortex, as Eccles suggested. Rather, as Popper claimed, self-conscious mind is conceived best as an emergent property of a specifiable brain organization.

This mechanism has direct relevance for the mind/brain problem. Note that storage takes place in the spectral domain. Images and other mental contents as such are not stored, nor are they "localized" in the brain. Rather, by virtue of the operation of the local brain circuitry, usually with the aid of sensory input from the environment, images and mental events emerge and are constructed. The images *are* Gilbert Ryle's (1949) ghosts resulting from the operations of the "machine" (brain). But, when implemented (i.e., realized, materialized) through action (i.e., in the organism's environment), these ghosts *can* causally influence, through the senses, the subsequent operations of the brain.

A similar mechanism involving the motor mechanisms of the brain can account for intentional, planned behavior. The evidence that such a mechanism exists is presented in *Languages of the Brain* and elsewhere (Pribram, 1971a, 1976; Pribram et al., 1981). Much of my laboratory research has been involved in demonstrating that brain function is active, not passive, in its interactions with environment, and in elucidating the processes operative in this active aspect of mind. This research has shown that the intrinsic cortex and the limbic formations of the forebrain actively organize sensory input (see review by Pribram, 1980).

I have belabored this neurophysiology because the discovery that certain operations of the brain can be understood best in terms of processing in the spectral domain is directly related to the discovery in quantum and nuclear physics that ultimately the appearances of matter may be immaterial. We must take a close look at this database so fundamental to a materialist view.

Ontology

The Dematerialization of Energy

The fundamental assumption that has given rise to the mind/brain problem is that mental phenomena and the material universe are in some essential fashion different 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 complementarity 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 matter 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 energy, potentials for doing work when interfaced with matter. It is this potential that, I propose, is neutral to the mental–material duality.

Energy and Entropy (Informational Structure) as the Neutral Potential

In science, such potentials are defined in terms of the actual or possible work that is necessary for realization to occur and are labeled *energy*. Thus, multiple realizations 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 has structure.

Heisenberg (1959) developed a matrix approach to understanding the organization of energy potentials. Currently, this approach is used in s-matrix, bootstrap theories of quantum and nuclear physics by Henry Stapp (1965) and Geoffry Chew (1966). These investigators (among others, i.e., Dirac, 1951) have pointed out that measures of energy potential 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. 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 space–time order.

In terms of the proposition put forward by Stapp and Chew, this means that the organization of energy potentials 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 such enfolded orders. Dennis Gabor (1946, 1948), the inventor of the hologram, based his discovery on the fact that one can store interference patterns of waveforms produced by the reflection or refraction of light from an object on a photographic film and reconstruct from such a film the image of the object. 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.

More Neuroscience

The Fourier theorem has also played an important role in the recent discoveries in the brain sciences that were reviewed in part in the section on the neural microstructure. 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 and was coined by Fergus Campbell and John Robson (1968) of Cambridge University when they 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 spectral form of description of patterns.

In the late 1950s and 1960s, David Hubel and Thorsten Wiesel (1959, 1968) had discovered that single cells in the visual cortex responded best when the visual system was stimulated with lines at a certain orientation. In the early and mid 1970s, Daniel Pollen and his colleagues (Pollen, Lee, & Taylor, 1971; Pollen & Taylor, 1974) noted that when such lines were drifted across the visual field, the response of the cell was not uniform but described a waveform similar to that which described the gratings used by Fergus Campbell. Campbell (1974) meanwhile showed that the responses of single cells in the visual cortex also adapted to the harmonics of the gratings that were presented, much as did the organism as a whole. Finally, Russell and Karen DeValois and their collaborators, (DeValois, Albrecht, & Thorell, 1978a, 1978b; DeValois & DeValois, 1980; DeValois, DeValois, & Yund, 1979) demonstrated that the response of these visual cortical cells is only poorly described by the orientation of a line, whereas it is accurately described in terms of the orientation and spatial frequency of a grating, that is, the cell is tuned to a spatial frequency range of approximately one-half to one octave. Furthermore, these investigators showed that when checkerboards and plaids were used to stimulate the visual system, the cells responded maximally to the Fourier transform of the space–time patterns, as determined by computer display, and that the cells were essentially unresponsive to the orientation of the individual lines that composed the checkerboards and plaids. In short, it appears that the visual system performs a Fourier transform on the retinal image produced by the lens of the eye.

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 optical 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. There are, however, 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 transform that best describes the process in the visual system is a Gabor, not a Fourier. The Gabor transform (1946, 1948; 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 not global, and it 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 (FFT) 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 fine-grain processing potential.

The dual properties of an enfolded fine-grain (technically, the 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 somasthetic modalities, Walter Freeman (1960) conducted studies in the olfactory, 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, which we perceive and which can be described in terms of Euclidean and Newtonian views and mapped in Cartesian space–time coordinates. This other class of orders is constituted of fine-grain organizations that describe potentials that had been poorly understood because of the radical changes that occur in the transformational process of realization. When a potential is realized, information becomes unfolded into its ordinary space–time appearance; in the other direction, the transformation enfolds and distributes 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, complete understanding involves at least a duality: On the one hand, there are enfolded orders manifested as energy potential; on the other, there are unfolded orders manifested in negentropic space–time.

Is Information Material or Mental?

Furthermore, when forces are postulated to exist between material bodies, the forces are often conceptualized as "material" even though they themselves are not constituted of matter. When matter and energy are related by the equation $E = mc^2$, energy is commonly assumed to be "material." But this is a misreading of the equal sign. The equal sign does not indicate sameness: For instance, $2 + 2 = 4$ and $2 \times 2 = 4$. If the equal sign indicated sameness, "×" and "+" would be the same, but they are not: $2 + 2 = 2 \times 2$ because they are equal though different. This is a point I have had to make repeatedly when I present evidence that men and women are biologically and psychologically different. I am *not* arguing, therefore, that they are unequal.

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 a 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.

Conclusions

A New Duality: The World of Appearances Versus the World of Potentiality

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 differences 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 a constructional realism.

What are these questions? Recall that Popper and Eccles proposed entirely different—and, in a fundamental sense, opposite—views of how mind and brain interact. In Popper's view, mind is an emergent from brain functioning; according to Eccles, mind operates on the intrinsic "liaison" formations of brain cortex. Still, these authors managed to publish a book together. Each must have felt some affinity for the other's views. What is it that they may have sensed to be in common? What deep feeling did they fail to articulate adequately in their book?

I believe that the analysis provided earlier in this essay may help clear up this issue. Note that when one looks downward in the hierarchy of systems that compose the ordinary world of appearances, essentially reductive analyses are engaged. To take account of new properties that arise, when components become organized into higher order, more complex structures, "emergence" is proposed; the proposal is essentially descriptive of what is observed. The upward look in the hierarchy, as in the phenomenal and existential approaches, simply takes these "emergents" as the fundamental achievements of observations. Constructional realism is compatible with such views of emergence, and as noted earlier, I believe Popper was attempting to achieve a similar end by his construction of World 3.

Eccles by contrast was holding out for a very different sort of formulation. He insisted that mind transcends brain function in that mind operates upon brain, not because mind emerges from the functioning of the brain. As noted above, articulated in this fashion, Eccles's formulation makes no scientific sense.

But now consider the brain as a spectral analyzer and the general characteristics of the transforms that occur. These characteristics have been appreciated fully only recently. The recording of spectral patterns by holography has provided a visible artifact whose properties can be readily conceptualized.

Essentially, space and time become enfolded in the holographic domain. This accounts for translational invariance, the fact that transformation into the ordinary domain can be accomplished from any part of the encoded record. In the holographic record, information becomes distributed, spread over the entire surface of a photographic film, or brain module, much as the waves produced by throwing a pebble into a pond spread to its edges. Several such waves initiated by several pebbles will interact or "interfere," and the record of these interference patterns constitutes the hologram. If a moving picture were made of the origin and development of the interference patterns, the movie could be reversed and the image of the pebbles striking the pond could be recovered. Image reconstruction by holography accomplishes much the same effect by an operation that performs an inverse transform on the record. Thus image (and object) and holographic record are transforms of each other, and the transformations involved are readily reversible.

Consider further the fact that in the holographic domain space and time are enfolded. Only the density of occurrences is manifest. These densities can be recorded as wave number or in scattering matrices representing n-dimensional (Hilbert) domains such as have been used in quantum physics. Holography has become a window through which we are able to conceptualize a universe totally different from that which characterizes the world of appearances. David Bohm (1971, 1973) pointed out that most of our conceptions of the physical world depend on what we can observe through lenses. Lenses focus, objectify, and draw boundaries between parts. Lenses particularize. Holograms by contrast are distributive, unbounded, and holistic. Bohm referred to our lens-given ordinary perceptions and conceptions as explicate and those that are holographic as implicate. Thus, there are at least two discernible orders in the universe: an explicate and an implicate. The explicate order gives an account in terms of particles, objects, and images. The implicate order, still poorly cognized, begins with densities of the fluctuating properties of waveforms.

Bohm and other physicists have become excited by the similarity of conceptualizations of the implicate order and those described by mystics who have experienced a variety of religious and other "paranormal" phenomena (Bohm, 1976; Capra, 1975). The lack of spatial and temporal boundaries, the holographic characteristic that the whole is represented in every part, and the transformational character of shifting from explicate to implicate order are all beyond ordinary human experiencing, which apparently is limited to the everyday, explicate, Euclidean–Newtonian universe to which we have become accustomed.

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 implicate 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.

The fact that the brain is, among other things, a spectral analyzer, that it encodes information in a distributed fashion akin to that which characterizes a hologram, also means that the structural boundaries that characterize the ordinary limits of "brain" and "body" can, on occasion, appear to be transcended. Take as an example our current-day world in a large city. The space surrounding us is filled with spectral forms generated by radio and television stations. We are insensitive to these spectral forms unless we obtain the use of a receiver tunable to one or another of the spectral forms. Only then do we "explicate" into the everyday domain the spectral forms broadcast and enfolded in the space about us. The "mystery" of mind is resolved not by holding to the neo-Cartesian view that Eccles has taken, which is inappropriate to Popper's formulation, nor by adhering to either the materialist or the mentalist stance. Rather, we must recognize the transformational and potential nature of the implicate domain and the fact that our sense organs "make sense" by tuning in (and out) selective portions of this domain.

Summary

In concluding, I will attempt to summarize my position as developed in this article. I began by accepting a dualistic view of everyday experience: We humans can distinguish clearly between the process of experiencing and the contents of that experience. In the centuries since Descartes, this led to the view that the process of experiencing is mental whereas the components of experience, if not themselves material, are at least indicators of a material, physical world. I then went on to show that modern physicists, working both at the microphysical quantum and nuclear level and at the macrophysical "universe" level, have called into question the material basis of matter. Matter is constituted of energy, which in several forms interacts to produce that which we normally experience in ordinary perception. Normal experience is characterized by Euclidean geometry and Newtonian mechanics. Thus, the material nature of matter is limited to the ordinary world of experience, unless one wants to adopt the bias that energy is material because it can be converted to matter as indicated by Einstein's equation, $E = mc^2$. But then why would we have to call such a transformation a conversion? Does not such a materialist bias cloud rather than clarify the fact that, as yet, we do not know how to properly characterize such energy forms? And by this question I do not wish to suggest that they be characterized as mental.

Beginning from the other end of the mental–material dichotomy, we run into a similar limitation on its usefulness. Information and information processing, as when a computer is programmed or a brain is informed by sensory signals, are shown to involve minute amounts of energy that can organize or reorganize large-scale systems. The configurations that energy systems display rather than their raw amount are shown to be critical. Are such figural changes to be conceived as mental or material when they involve languages, cultures, and so on? Once again, a limit is reached where the mental–material distinction becomes useless.

Next I analyzed the issue of dualism on its own ground, that is, within the purview of ordinary experience. Here dualism is found to be based on mirror-image views constituted by different analytic procedures. The reductive materialistic view held by most scientists is found by looking downward from one's experience into the hierarchy of components that constitute that experience. This reductive view is balanced ordinarily by the recognition that novel properties "emerge" when specific configurations of components are formed.

Looking upward from one's experiences involves validating the experience with that of others. Experienced "phenomena" are described and compared. Emphasis is on the existence of the experience per se, its existential nature, and when precision is attempted the emphasis is on the structural relationships among phenomena. Consensual validation, enactment, and structural analysis of relationships constitute the tool of enquiry, not separation into parts causally related to one another as in the reductive sciences. Thus, the language of phenomenology, existentialism, and structuralism is "mental" because it is experience per se that constitutes the focus of interest.

Recognition of the procedural difference that is responsible for dualism in the ordinary world of experience allows one to transcend this dualism without denying its usefulness to deal with the problems of that ordinary world. I propose that dualism can be transcended by carefully combining the techniques and results of both the reductive and the phenomenal approaches to enquiry. Structure having been made the central, enduring, single quality of a pluralistic monism, both reductive entities and phenomena are seen as realizations of identical structures derived from a more basic existential given.

Once this constructional realism is formulated, however, it has to face another issue. True, dualism is not denied; it simply is shown to operate in a limited sphere. But transcending dualism with a structural monism violates the very spirit of what dualists and mentalists believe in and are trying to articulate: the unique character of mental processes and their contents.

My final proposal meets the requirement of this aspect of dualism. Brain physiologists have shown the nervous system to be, among other things, a spectral analyzer. Furthermore, input apparently becomes distributed and stored in the transform domain in the manner of a holographic record. And physicists have suggested that a holographic-like order may well characterize the microstructure of the physical world. In this domain, space and time become enfolded; only density of occurrences is represented.

Descriptions of this domain and other similar orders that account for the observations of modern physics seem to be remarkably similar to mystics' descriptions of paranormal and religious experiences. I propose, therefore, that the duality between the normal, everyday domain of appearances and the transform domain captures the concerns of mentalists and dualists and accounts in a specific and precise mathematical fashion for what hitherto has been incomprehensible.

Structural realism is thus primarily a neutral monism that deals with a number of dualities of which two are especially significant for unpacking the issues involved in a mind/brain dualism: (a) a procedural duality that faces upward and downward in the hierarchy of systems discerned in the ordinary world of appearances and (b) a transformational duality that apposes the ordinary world of appearances to that viewed through the window of the spectral transform domain characterized by descriptions akin to those of the experiences of mystics that provide the basis for some important insights in various religious traditions.

Other dualities may well be discovered to underlie as yet unarticulated premises of dualism. What appears clear at the moment is that a dualism based on the distinction between mental and material is too limited to deal with the very issues that it poses. Other dualities can articulate answers to the problems raised by these issues and can deal not only with their substance but also with their spirit. Furthermore, these dualities can be specified by scientifically sound procedures and mathematically precise formulations that are encompassed by an ontological neutral monism from which an epistemological plurality of duals are constructed. Finally, their constructions are known to stem directly from discoveries in the physical, information, and behavioral sciences. Thus the often-made argument that the results of scientific research have no bearing on philosophically framed issues has been shown to be wrong. In fact, what has been shown is that only through the results of scientific research can philosophical issues, even at the ontological level, be refreshed.

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