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'Holism' could close cognition era

By Karl H. Pribram

It is 1985, and psychology in the United States is divided. Experimentalists and academics are dissatisfied with the growth of professionalism, and clinical and humanistic professionals cannot see the relevance of current experiments to the practical concerns of the field.

The ailment is of long standing, and seems intractable. But I believe that a new look is in order, and that the landscape before us heralds a remedy, if only we can accept what we see.

One of the major blocks to acceptance is the overwhelming concern of 20th century scientists with method and technique. This concern has made psychology a respectable science but, as with every advance, some disadvantages have accrued. I do not propose that we throw out the baby with the bathwater — only that it is time for a change of bathwater.

The overarching concern with method is expressed in terms such as the "hard" and the "soft" parts of psychology (when in fact the soft often exceed the hard in the rigor of their experimental design), in the ambivalence of the clinicial toward scientific psychology, and in the disdain of the experimentalist for the thought processes demanded in the clinic.

According to this view we need search no further, and as long as we cannot change our methods, by virtue of the interest we pursue, we cannot change what ails us.

I believe this view to be false. In fact, method and technique have unified psychology. Differences in subject matter — instrumental behavior, social behavior, verbal reports of subjective experience, psychophysics, man-machine interfaces — have been considerably more divisive than method. We all share a faith in statistics and apply these techniques whenever they are appropriate, and sometimes even when they are not. We all believe in experimental design (other disciplines such as neuroanatomy and neurophysiology have hardly heard of such an approach to research), and apply it whenever feasible. If we are clinicians we accept or reject findings on the basis of this common belief in method.

It is the difference in regnant paradigms, not method, which differentiates the various divisions in psychology. At the core, I believe the problem is that experimental psychology's journey from behaviorism to cognitive psychology has been but a beginning. Until that journey is taken a step further, psychology will remain fragmented. I also believe the time is ripe for taking this next step and I want to make this an opportunity to outline the direction it will go.

Perspective

In the decade between 1955 and 1965, a paradigm shift took place in psychology. This shift, which has come to be known as the cognitive revolution, came about by virtue of a convergence of technological innovation, mathematical invention and a host of findings in the neurosciences. Among the remarkable accomplishments of the decade were: Information measurement in communication; servomechanisms in control systems; computers and programming techniques to analyze problem-solving; studies of natural language grammars with the aid of symbolic logic; and the analysis of learning from the vantage of sampling and decision theories.

The neurosciences also made critical contributions. Neuropsychology, which had come into disrepute because of a failure to provide reliable data, was shown to be viable once the proper techniques were employed. More important at the time, neurophysiology showed that feedbacks rather than reflex arcs were the elementary circuits in the nervous system. Thus the brain was shown to be capable of controlling its input and organisms were seen as actively operating on their environments. A simple stimulus-response chain, even with intervening variables and hypothetical constructs, did not reflect the actuality of how the organism was put together.

Finally, it was shown that dishabituation could occur whenever any aspect of a repetitive situation was altered, even when the alteration involved attenuation or absence of the stimulus. The brains of mammals, at least, make

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"neuronal models" of their inputs, models against which subsequent inputs were processed. Such neuronal models act as representations, and processing constituted computations among representations.

Cognitive psychology centers on studying the active computations which guide organisms in solving problems. Computer programs are vehicles by which computations can be accomplished. Information measurement and other mathematical techniques aid in the construction of problem-solving programs. Programs are languages. The revolution was underway.

Today

All of psychology has not become cognitive. Methodological behaviorists continue to demonstrate their strength in devising rigorous experiments. Radical behaviorists continue to decry the ambiguity of natural language and the resulting impossibility of a science of subjective experience. Existentialists and phenomenalists insist that behavior is not the essence of psychology — that subjective experience is what motivates all of us to enter the field. Clinicians have to deal with the verbal reports of introspections, but aspire to have reliable tests that will validate such reports.

Cognitive psychology has at least helped clinicians in their aspirations. The current surge of excellent work in clinical neuropsychology is but one example of linking an analysis of verbal reports with quantitative behavioral testing.

But cognitive psychology itself is beginning to feel its age. The vitality which characterized the revolution is ebbing. More and more experimentalists are concerned with refinements and, to outsiders, sometimes with trivia. There are suggestions of "burn-out" — that the revolution has come to an end, that activity will come to a standstill when it is realized that, after all, the radical behaviorists are right: language is too ambiguous to serve as the core of a science.

I see the matter differently. I, too, see the ending of the 1955-1965 revolution. But I also see the beginning of the next turn of the wheel, the coming revolution of 1985-1995.

What's Wrong?

What is wrong with the current paradigm in cognitive psychology is that it is based solely on analogy with the serial processing computer and Von Neuman architecture. Serial programming is excellent for symbol manipulation, but fails to provide access to the richness of texture involved in image processing. And all thought is not imageless.

The deficiency is compounded by the view that, in the nervous system, serial architecture is represented by a hierarchical Euclidian system in which single elements, single neurons, serve as detectors of single features, single percepts, single cognitions. An otherwise excellent recent text in neuropsychology is based on the concept of a "cognon," a neuron which represents a cognition. In psychophysics, a channel is identified, implicitly or explicitly, with a neuron.

The identification of an idea with a neuron is not new. Bain, in the 19th century, held such a view. It is worth recalling on this 100th anniversary of the publication of Ebbinghaus' treatise on memory, his view of the matter: "The curious theory of Bain and others that each idea is lodged in a separate ganglion cell [is] an hypothesis impossible both psychologically and physiologically."

Why would this identification of percepts and cognitions with single neurons be of such importance to a pioneer psychologist? Why is it important today? The reason can be expressed in terms of mind/brain isomorphism. If indeed neurons correspond to our introspections, the entire cognitive enterprise is built on a faulty premise.

I am writing this essay on my word processor. According to the one neuron/one idea proposal there should be a single switch somewhere in my computer which represents the word computer and another which represents the word isomorphism. Or at least there should be a chip which constitutes such a representation. "Utter nonsense!" says the computer scientist. Then why does the cognitive scientist whose model is, and whose modelling uses, the computer and its programs so extensively, accept without question the current neurophysiological "dogma"?

In fact, the neurophysiological evidence is against the one idea/one neuron concept. Each neuron, even in the primary sensory cortices, is selective of several features, not one. Sets of neurons display different conjunctions of feature selectivity. This suggests that spatially arranged patterns of neurons, not single neurons, read out specific features to the next stage of processing. Occasionally in a network of such spatial patterns a node forms which responds more vigorously to a particular conjunction of features under investigation: thus the pontifical "grandmother" cell of which so much has been made in textbooks. But close inquiry in the laboratory shows that such pontifical cells also respond to other properties of the stimulus, albeit not as vigorously as to one specific conjunction. I would not be surprised if one could occasionally identify a chip or even a switch in the hardware of a computer which responds more vigorously when some feature in assembly language was being processed.

Another aspect of the current malaise in cognitive psychology is its relationship to AI, artificial intelligence. Much of what goes on under this label aims at enhancing problem solution and surpassing human capability. But a respectable group within AI is interested in how humans solve problems. Often this group simply introspects and attempts to use our notoriously ambiguous natural language to construct computer simulations. These often have the appearance of rigor, but the basic premises upon which they are formulated are never examined.

Tomorrow

Already, however, there is a fresh wind blowing. The impetus comes from the construction of parallel processing architectures, which allow content-addressable rather than location-addressable programming. This architecture resembles that of the brain much more than today's serially operating devices. The ambiguity of natural language is being replaced by more precise linguistic formulations. This allows a diminution of the ambiguity inherent in verbal reports of problem-solving and perceptual experience. The ambiguity is further reduced by clinical applications, especially in those where brain damage is being examined.

Further, mathematical descriptions which can be implemented more readily in parallel networks are becoming influential. Already convolution and matrix models are pitted against each other as explanatory of pattern perception, categorizing, and serial order effects in memory. These models fit neuroanatomical, neurophysiological and neurobehavioral data much more closely than do less sophisticated feature hierarchy models. And, what is most important, there is room in these models for precise descriptions of processes which lead to intuitions, affects, attention and intention.

These mathematical models range well beyond the statistics which have proved so useful in the social sciences. The mathematical developments in the 19th century can be dated from Fourier's discovery, which showed that every pattern, no matter how complex, can be analyzed into simple component regular wave forms that differ only in amplitude, frequency and relationship to one another.

The Fourier process yields a dimensionality, a "space," in which information becomes distributed and thus enfolded in every portion of the "space." Thus space and time, as we perceive them, become distributed and enfolded, and are no longer the dimensions being processed. In the absence of explicit space and time dimensions, as noted by Gabor in his pioneering paper published in 1946, causality also disappears.

Gabor's analysis of acoustic and visual processing led to his mathmatical invention of holography and current engineering techniques of visual processing. Holographic representations represent this distributed, enfolded domain, and there is now an imposing body of evidence that the microstructure of receptive field properties of neurons in the primary sensory systems can be modelled in Gabor mathematics.

Another major mathematical formulation of the late 19th century was the formulation by Boltzman of the second law of thermodynamics. This formulation has more recently been developed by Prigogine into the mathematics of dissipative structures, structures which dissipate entropy (disorder) by establishing temporary stabilities far from equilibrium. Life, biochemical and neural, is characterized by such self-organizing processes.

These distributed and dissipative mathematical formulations are much more readily implemented in the parallel computer architectures currently under development. Psychologists are utilizing these formulations to describe facets of memory and other cognitive processes. Thus James Anderson and his colleagues at Brown University have been engaged in modelling the categorical aspects of memory by matrix models. Ben Murdock at the University of Toronto has implemented convolutional mathematics to handle serial order effects. I have recently provided neuropsychological evidence sugguesting that the brain can work in either the matrix or the convolutional mode, depending on processing demands. Geoffrey Hinton and his group at Carnegie-Mellon University have developed Boltzman "machines" to characterize still other aspects of problem solution.

What's in a name?

These, then, are the developments which I believe will make psychology whole once again. When George Miller, Eugene Galanter and I found ourselves in transit from behaviorism to cognitive psychology, we noted that we were really "subjective behaviorists" and laughed at the paradox which, at that time, that term seemed to imply. We also noted that, to cope with the subjective portion of our agenda, we would have to develop a new set of scientific procedures. We suggested that enactment of subjective experience by computer simulation would serve this purpose. I view computer simulation as akin to the "in vitro" experiments performed in biochemistry, the computer serving as the test tube.

The problem with current cognitive psychology is that its simulations are pretty well limited to intentional problem-solving behavior and to perceptual experience; it has done rather poorly with the latter. Plans as programs are working well; programs as image processors have fared poorly. In the 1950s we were convinced that within a decade we would have machines that would produce finished hard copy manuscripts from verbal dictation, that translations from one natural language to another would soon follow. These expectations are as yet unfulfilled, due to the intractibility of image processing by current serial processing architecture and programming.

Emotions and motivations as root dispositions, thus far, also have been inaccessible to enactment. Such dispositional variables may well become accessible to simulation when the parallel architecture and quantum distributed and thermodynamic dissipative mathematics are applied.

In the 19th century, cognition was joined to conation and affect to compose psychology. I doubt that the current changes in psychology

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will be termed conative or affective, but the changes portend in this direction. To make psychology whole, its regnant paradigm must truly reflect the totality of subjective behaviorism, not a paradigm that is limited to perception and cognition, to problem solving and "information processing." The structuring of "redundancy" in terms of familiarity and novelty has been neglected except for a few pioneers such as Tex Gardner, George Miller and Herb Simon (on chunking and the magical number). It is the dimension of familiarity/novelty, not amount of information, which influences arousal. Modelling the apparatus by which chunking occurs, and the modelling of graph structures in general, is bound to benefit greatly from the availability of parallel processing architectures and programs based on matrix and convolutional mathematics.

What will be the name of this next turn in the development of scientific and professional psychology? It is hard to predict. I would like to see the label "holistic" become respectable. For not only is the whole greater than and different from the sum of its parts, as the Gestalt psychologists were wont to point out, but the whole can under certain conditions also become enfolded in all its "parts." Thus each "part" represents the whole, as in a hologram. Convolutional and matrix mathematics, the distributed and dissipative structures we are coming to know, allow holistic discriptions to be as rigorously scientific and precise as any that have been used in physics, chemistry and biology.

At the same time, these developments in mathematics and computer architecture allow us to model psychological processes as diverse as imaging and intuition, as respectible as sensory psychophysics and as non-sensical (non-sensory) as mystical experience. For a half-century, quantum physicists such as Niels Bohr, Schrödinger, Einstein and Heisenberg shared their insights with us by pointing out the similarity of their findings with those of the Veda and Upanishids and other spiritual disciplines. Is it not time that psychology listens, places the Newtonian cosmology in perspective and comes to grips, where relevant, with the models developed in 19th and 20th century mathematics and physics?

The transition from behaviorism, especially stimulus-response behaviorism, to cognitive psychology was characterized by an increasing difficulty with operationalizing such concepts as drive, and an increasing ability to operationalize such concepts as effort and attention. I believe that the next revolutionary turn in psychology will, in a similar way, be characterized by an increasing difficulty in operationalizing concepts we now hold dear, such as information processing, and by and increasing ability to operationalize such concepts as meaning and intuition. The 21st century is beckoning, and I predict advances in psychology, both as a science and in practice, which will rival those in the biology, the chemistry and the physics of the 20th. This is my faith. □

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