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NEUROLOGICAL NOTES ON KNOWING

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INTRODUCTION

A discussion of the "neurology of knowing" presupposes some considerable knowledge about knowledge and about the way the brain functions. My thesis here is that we do in fact have available a great body of analysis and evidence; thus, matching the psychological against the neurological can effectively increase the relevance of both.

Let me define, for the purposes of this presentation, knowledge as codified information consensually validated. Lest the reader be turned off completely by this seemingly restrictive statement, let me add quickly that the definition portends not all what it seems to. It is derived from a long series of studies performed in my laboratories aimed at the problem of how the brain works while an organism is learning, remembering or forgetting. Again and again my experiments showed that how much may be learned or remembered—indeed even *what* may be learned or remembered—is at any moment determined as much by the context, the set and setting, in which an informative item is placed as by that item *per se*. Further, I found that we did not know how to manipulate the content-context relationship, or even how to think about it: We knew that somehow repetition was essential but knew little about which forms of repetition were effective and which were not. Finally, it became apparent that these patterns of repetition constitute codes and that cracking the codes would be tantamount to understanding how information storage and retrieval are best accomplished.

In short, my proposal is that the extent of learning, remembering and forgetting depends on the codes into which events are patterned—and that it is coding which determines knowledge. By this I do *not* want to convey just another statement of the Sapir-Whorf hypothesis. Rather I have in mind something similar to Charles Peirce's Theory of Meaning. But more of this in a moment.

CODES

First, what is a code? Not so long ago my laboratory came into the proud possession of a computer. Very quickly we learned the fun of communicating with this mechanical mentor. Our first encounter involved twelve rather mysterious switches which had to be set in a sequence of patterns, each pattern to be deposited in the computer memory before resetting the switches. Twenty such instructions or patterns constituted what is called the "bootstrap" program. After this had been entered we could talk to the computer—and it to us—via an attached teletype.

Bootstrapping is not necessarily an occasional occurrence. Whenever a fairly serious mistake is made—and mistakes were made often at the beginning—the computer's memory is disrupted and we must start anew by bootstrapping.

Imagine setting a dozen switches twenty times and repeating the process from the beginning every time an error is committed.

U	U	D	D	U	U	U	D	U	D	U	D
U	U	U	U	U	U	U	U	U	D	D	D
U	U	U	U	D	U	D	U	D	U	U	U
U	U	D	D	U	U	U	U	U	U	U	U
U	U	D	D	U	U	U	D	U	U	D	D
D	D	U	D	D	D	U	D	D	U	U	U
U	D	U	D	D	U	D	U	U	D	U	D
U	D	U	D	U	U	U	U	U	U	D	U
D	U	D	D	U	U	U	U	U	U	U	U
D	U	U	U	U	U	U	U	D	D	U	U

and so on.

Imagine our annoyance when the bootstrap didn't work because perhaps on setting the 19th instruction an error was made in setting the eighth switch. Obviously, this was no way to proceed.

Computer programmers had early faced this problem and solved it simply. Conceptually, the twelve switches were divided into four triads and each combination of up down within each triad given an Arabic numeral. Thus

D	D	D	became	0
D	D	U	became	1
D	U	D	became	2
D	U	U	became	3
U	D	D	became	4
U	D	U	became	5
U	U	D	became	6
U	U	U	became	7

Conceptually, switching the first toggle on the right becomes a one, the next left becomes a 2, the next after this a 4 (and the next an 8 if more than a triad of switches had been necessary, i.e., if for instance our computer had come with sixteen switches we should have conceptually divided the array into quads). Thus the bootstrapping program now consisted of a sequence of twenty patterns of four Arabic numerals

e.g.	3	7	2	2
	0	0	1	4
	3	4	5	6
	2	2	1	3
	1	0	3	7

etc.,

and we were surprised at how quickly those who bootsrapped repeatedly, actually came to know the program by heart. Certainly fewer errors were made in depositing the necessary configurations—the entire process was speeded and became, in most cases, rapidly routine and habitual.

Once the computer is bootstrapped it can be talked to in simple alphabetical terms: e.g., JMP for jump, CLA for clear the accumulator, TAD for add, etc. But each of these mnemonic symbols merely stands for a configuration of switches. In fact, in the computer handbook the arrangement for each mnemonic is given in Arabic notation: e.g., CLA = 7200. This in turn is easily translated into U U U D U D D D D D D D, should we be forced to set the switches by hand because the teletype has gone out of commission.

Programming thus is found to be in the first instance the art of devising codes, codes that facilitate learning, remembering and reasoning. The logic of a computer is primarily a code, a set of signals which allows ready manipulation. The power of a program lies in the fact that it is a useful code.

If you doubt this, try next month to check your bank statement against your record of expenditures and do it all using Roman rather than Arabic numerals. Can you imagine working out our national budget in the Roman system?

I have belabored this point because I believe that coding operations are central to what we call "knowing." I might even go so far as to suggest that knowing is coding.

What then are the forms coding can take? Here the results of research in brain function prove to be helpful. The nervous system, just as the computer, has as its primary signalling device an on-off type of process. The nervous system, just as the programmer, has to find ways by which to convert sequences of patterns of on-off events into usable, i.e., processable, codes. This is accomplished in the nervous system by the arrangement of inhibitory mechanisms which act to group signals and to allow time for depositing them. Grouping is accomplished by the process of lateral or surround inhibition through which the activity in one neuron causes a decrementing of activity in its neighbors; time for deposit depends on the process of neuronal self-inhibition through which a neuron relatively quickly decrements its own activity through negative feedback. Inhibitory mechanisms allow the occurrence of an alphabet of states to supplant the restrictions imposed by coding solely by on-off patterns of nerve impulses. Thus a simple neural alphabet (such as that composed of Arabic numerals in our initial bootstrap programming of the computer) can be manipulated by our input systems. A complex series of patterns of very simple on-off elements has been coded into a simpler series of patterns of somewhat more complex elements. The analogy with computer mechanisms can be carried even further: a hardware wiring diagram by which such transformations might be accomplished in a computer looks remarkably similar to a diagram of the organization of the retinal structure known to organize the living visual process. This exchange between a non-repetitive series of patterns made up of repetitive elements and a repetitive series of patterns made up of non-repetitive elements is the essence of coding.

One of the fascinating things we have learned about the operation of the brain is that, within any of its systems, information becomes distributed. Extensive removals and injuries impair performance remarkably little (until some critical point is reached). I have elsewhere detailed a type of mechanism (considered to be similar to that by which holograms are made) consonant with the known facts of neuroanatomy and neurophysiology which can accomplish such distribution of information (Pribram, 1966, 1969, and 1971).

IMAGES

Here it is sufficient to note that such a mechanism actually allows the construction and reconstruction of Images by a process in which only a limited number of variables need be coded. This then would be a degradation of the neural alphabet back into simpler components. However, these components are now no longer the presence or absence (on and off) of neural impulses but are indicators of relationships among them. Imaging therefore involves a *further* coding process by which the neural process can represent fully its origin. This isomorphism between environmental occurrences (events) and Image results from the fact that all of the transformations performed on the signalling events are completely reversible.

Composed as it is of few elements arranged in complex series of patterns, the Image thus resembles, as it should, the environmental pattern from which it originates. This is a resemblance only, however; as we have seen, the elements composing the Image represent relations between events rather than the events *per se*. That this is so, is most dramatically demonstrated by the experiments in which a subject is fitted with prism glasses which invert his entire visual field. As is now well known, reasonably rapid adjustment takes place so that the visual image is restored to its accustomed upright form (Held, 1968; Kohler, 1964).

Analysis of the brain's function has shown further that at least three different sorts of Images can be constructed. The first of these, already discussed, is initiated by and operates on sensory events generated at receptors which interface the organism with his physical and social environment—receptors located in the eyes, ears, nose, mouth, and skin. Another type of Image is constructed from events occurring deep in the central nervous system. Research over the past few decades has shown that the central core of the brain stem contains a variety of receptors, each sensitive to physico-chemical changes occurring in the organism's blood stream. Thus, cells sensitive to temperature, estrogens, androgens and adrenal steroids, osmotic equilibrium, blood glucose, sertonin, noradrenalin and the partial pressure of circulating CO_2 are located in a limited part of the brain surrounding the midline ventricular system and extending from just anterior to the hypothalamus to the lower part of the brain stem. These sensitive core-receptors regulate the production and conservation of heat, the sexual activities, thirst and hunger, the sleep and respiratory cycles of the organism (Pribram, 1960). Awareness of these processes must be based on some sort of Imaging. The Images constructed are, however, somewhat different from Images-of-Events of the world outside. Due to differences in receptor properties (e.g., core-receptors do not adapt) and differences in the organization of the neural processes engendered (e.g., there are probably no clearcut differences between lateral and self-inhibitory interactions), changes in the world-within are continuously monitored. Further, the neural mechanisms involved in the organization of the monitoring functions (e.g., the reticular formation in which the core-receptors are imbedded) are also sensitive to overall changes occurring in the world-outside. Monitor-Images therefore have the characteristic that they are induced by organismic state, i.e., by dispositions. Thus they are continuous rather than "thingy." Monitor-Images refer to subjective feelings whereas Images-of-Events make up the objective world of perceptions.

There is still another type of Image. The processes involved in its construction are movement-produced and movement-producing. Here again a large series of experiments is involved in making clear just what happens in the motor mechanism. Only a quarter of a century ago it was thought that the brain's motor cortex functioned as does a piano keyboard, that excitation of the appropriate neural element led to the contraction of a muscle or muscle group. Now we know that this is not so. Even at the simplest reflex level a large number of motor fibers (the α efferents) lead from the central nervous system not to muscles but to muscle spindles, receptors connected in parallel with muscle fibers. Excitation of these efferents to the spindle-receptors alters their activity—this is shown by changes which occur in the discharge of the afferent, sensory nerve fibers leading from the spindles to the central nervous system. The reflex mechanism can thus be activated either by operations performed on the muscle fiber (as when some external occurrence pushes or pulls) or by tuning the reflex to some new value via excitation or inhibition of the muscle spindle's activity. Research has shown that a good deal of the brain's control over movements is accomplished in this more subtle fashion (Miller, Galanter, and Pribram, 1960).

A corollary of the tuning process is the fact that such a mechanism is sensitive to the external forces which play on the muscles since they are hooked up in parallel with the spindles. Thus the sensory nerves from the spindles can relay information about force-fields to the brain—and in fact such sensory messages do reach the brain's cortex. Tracts from the periphery run rather directly to motor cortex where single cells (Malis, Pribram, and Kruger, 1953) have been found especially sensitive to the force necessary to perform an action (Evarts, 1967). Further, experiments have shown that a running record of changes in such force-fields allows a prediction to be made within millimeters of the extent and direction of the movement required next in order to continue effective action (Bernstein, 1967). These results have led me to call the Images constructed in the process of such endeavors, Images-of-Achievement.

Images-of-Achievement thus guide Actions (representations of such Images in the world external to the organism) rather than movements since these Images are composed of signals initiated by forces external to the organism. Images-of-Achievement guide movement, not by a piano keyboard type of process, but by tuning the reflex to accomplish an extrapolation of the "running record" (a wetware equivalent of a mathematical representation) of changes in the field of forces playing on the receptors which regulate the reflex. In this manner, Acts, representations of Images in the world-outside, are achieved.

IMMANENT KNOWLEDGE AND ACTION

Constructing Images thus constitutes three forms of knowing. We might call these the immanent forms. They are expressed in epistemology as Empiricism, Existentialism and Pragmatism, all rich in intuitive approaches to knowledge. All three hold that the criterion by which knowledge is known to be true is the *effect* such knowledge has: in Empiricism it is the effect on Images-of-Events; in Existentialism it is the effect on Monitor-Imaging; in Pragmatism it is the effect on Images-of-Achievement. Thus three forms of immanent knowing can be distinguished: knowing what, knowing that (in the sense, e.g., of obtaining carnal knowledge), and knowing how (see also Rozeboom's discussion of these forms in the present volume).

Despite the representational nature of these forms of knowing there remains the problem of the inherently personal nature of Imaging. The processes by which Images are constructed—though they employ constancies and other regularities recurrent in the brain's environment—occur entirely within the organism and thus tend to remain essentially private constructions. Polanyi (1960) has brought to our attention these personal processes. But, most analytical philosophers will insist that knowing must refer to something to be known and that this known cannot be ascertained without consensual validation. Consensual validation is not possible unless Actions, representations made in the organism's *environment*, are taken. The Acts necessary to establish knowledge are not simply come by. The neural mechanisms detailed in the next section show a rich intermeshing of Images-of-Achievement with those which produce Images-of-Events and Monitor-Images. Initially, as we shall see, these operations give rise to higher order (derived) knowledge. How then is immanence regained? Let me leave this topic for later and emphasize here the importance of Act to Knowledge, not in Brentano's sense but because to Act is to make a private process public. Thus, even though the process of Acting is highly personal and private, the Act once constructed becomes public. This accessibility of Action has major consequences.

SIGNS

Because of its privacy and also because of the richness of an Image similar to that found in uncoded "reality" there is considerable difficulty in sharing Immanent Knowledge directly. Other methods of coding do not share these difficulties. For instance, one process involves "decoding" the Image. Using this technique we identify aspects of the Image, assign them and work with these assignments. Neurologically, this process of identification is not yet fully explored. However, over the past two decades, studies performed in my laboratories and elsewhere have shown that those parts of the brain which had earlier been thought to serve associative functions, are more likely involved in the coding operations which lead to identifications of features of the Image (Pribram, 1960). These operations are similar to those already encountered in the production of neural signals from sensory events. In fact, the locus of operation may well be the same: We have evidence that the so-called cortical association areas of the brain work primarily to control input—in the visual and auditory modes, this control is exerted as far peripherally as the retina and the cochlear nucleus in the brain stem (Pribram, 1967; Spinelli and Pribram, 1966, 1967).

We found that this control is effected via structures in the brain which have motor functions (Reitz and Pribram, 1969). At first this presented us with an enigma; but on reflection it seemed less surprising. If motor mechanisms control movement by regulating muscle spindle receptors why is it odd that these same mechanisms should be found to control other receptor functions? Identification of features is after all an active process and the attaining of this perceptual skill is not that different from attaining a motor skill. The very same process which produces Images-of-Achievement must therefore come into play in decoding Images-of-Events.

Thus the very relationships to be Imaged are apparently under the influence of achievement control mechanisms. The processes which produce Images-of-Events and Images-of-Achievement are interdigitated to produce Signs. Significant (Sign-evoking) features of the Images-of-Events are enhanced when their identification is achieved through Action. We thus go about denoting: Indexing by means of Signs the universe which generated them.

Early in this manuscript we considered neural signals to be constructed into a primitive on-off alphabet of relationships among excitatory and inhibitory processes. The denotative Signs constructed by the cortical control mechanism can in a similar manner be viewed to represent neural words derived from higher order interactions coded when the processes which produce Images-of-Achievement operate on the processes which produce Images-of-Events. The alphabet constituted by neural inhibitory configurations would, therefore, correspond to the Arabic numerals used to determine the positions of each triad of switches. The Sign would correspond to the combinations of numbers used to bootstrap the computer.

In short, knowledge can be achieved through *Indexing* (categorization). Indexing goes beyond immanent knowledge by denoting, structuring the variety encompassed by the Image. In a sense meaning is imposed on the events by Indexing them; however, the imposition is derived from relationships among the events themselves. The knowledge which results is intrinsic if not immanent. As such it has the feel about it of being relevant though somewhat artificial—a code to be used to communicate about immanent knowledge but not to be confused with it. I can indicate to you by an identifying Sign that I know Jerome Bruner; neither you nor I confuse this indication as encompassing the richness and complexity of my Image of the person indicated.

SYMBOLS

One would expect a somewhat different result when the processes which generate Images-of-Achievement operate on, interact with, those which produce Monitor-Images. Evidence has accumulated that such interactions also occur. This evidence suggests, though somewhat indirectly, that Symbols are derived from such interactions. Symbols convey to the organism that his actions affect Monitor-Images, i.e., they engage his dispositions.

The evidence to which I refer is derived from the delayed reaction experiment. This task was devised by Hunter to show that young children and animals had ideas which could mediate in memory between an occurrence and its subsequent utilization (Hunter, 1913). While the subject watches, an experimenter hides a piece of chocolate or a peanut. The hiding place is then removed from view either by relocating the subject or by interposing a screen between subject and the hiding place. Some minutes (or even hours) later the hiding place is again exposed—the children and animals, of course, immediately search out the hidden tidbit. They show no difficulty with this task or any of its many modifications unless the frontal extremity of their brain is damaged. Only when the frontal cortex and a motor structure (the caudate nucleus) which lies deep to it are injured is this capacity to recall lost (Jacobsen, 1935; Rosvold and Szwarcbart, 1964).

Other considerations [anatomical and behavioral (Pribram, 1958)] show the frontal cortex to be intimately related to the core brain mechanisms which generate Monitor-Images. The question which has for decades puzzled investigators is the repeated finding that in the brain the mechanisms of recall and those dealing with appetites (or drives) are juxtaposed. (Initially the problem centered on the frontal cortex (Pribram, 1960); more recently the scene has shifted to limbic structures such as the amygdala (Bagshaw and Benzies, 1968; Bagshaw and Coppock, 1968; Bagshaw and Pribram, 1968; Pribram, 1967) and the hippocampus (Douglas, 1967; Douglas and Pribram, 1966); and now clinical evidence suggests that hypothalamic lesions markedly impair certain kinds of memory (Talland and Waugh, 1969).

These findings become less mysterious when the delayed reaction task is analyzed in terms of symbolic processing as conceived here. The problem can be altered slightly by using what is called the indirect method: a cue other than the tidbit itself can be used to indicate where the peanut or chocolate is to be hidden. Performance on the indirect is no different from that on the direct task. In the indirect case, however, the cue serves clearly as a token, a symbol of the action which will retrieve the tidbit. What cue is used is irrelevant—the token is arbitrarily associated to the disposition to retrieve the tidbit by the act of solving the problem.

The use of tokens has been explored using other techniques in chimpanzees. A Chimpomat was constructed on which the animal performed somewhat as people do on slot machines (Jacobsen, Wolfe, and Jackson, 1935). Chips were delivered upon appropriate action. These chips could later be turned in for a complement of peanuts. Chimps enjoy the Chimpomat—unless they are deprived of their frontal cortex. After such surgery tokens become meaningless, symbolic processes severely impaired.

Symbolization then, just as indexing, is a derivative of the interactions of processes which produce Images. In the case of Symbols the derivation is made from the interaction of the process which produce Images-of-Achievement with those which generate Monitor-Images. The Symbolic process involves Action, the construction of an external representation of what is going on in our brains. Symbols are thus expressions of feelings, expressions that come to represent the feelings in the world outside through use.

Symbols are thus different from indices: symbols are *not* isomorphic with the events they symbolize. As already noted symbols are constructed arbitrarily through use. Symbolic knowledge is thus paradoxically derived in large part from sources external to the events which they symbolize—they stem from the feelings to which they are addressed. A relationship is maintained between Feeling and Symbol—they are, as it were, grafted onto one another to produce a various and abundant crop.

DERIVATIVE AND LINGUISTIC KNOWLEDGE

Indexing and Symbolizing are therefore two ways of knowing that are considerably different from the Immanent mode. They are derived when Images are Acted upon. Indexing results from Action on Images-of-Events; Symbolizing occurs when Action concerns Monitor-Images. Since both Indexing and Symbolizing involve Action, the making of a representation external to the organism, derivative knowledge becomes quickly public and communicable.

In man this communicability appears to have taken a step beyond even the derivative knowledge of Signs and Symbols. Man manipulates Signs as Symbols: he uses signs arbitrarily. In the computer analogy we have been using, an alphabetical word is substituted for the numerical Sign word which indicates the switch position. This substitution brings about an increment of power at least equal to that provided by the initial coding operation. Now logical operations, rules, can be fashioned and applied since the relationship involved in Signing and Signifying can be made explicit. The very arbitrariness of the symbolic use (whether inductive or deductive) of Signs gives rise to the flexibility of language.

Man is also capable of using Symbols as Signs. He indexes symbolic representations by some sign or label, indicating their intrinsic attributes. Such signs become potent communicators when they code shared feelings. Human reasoning also may have its origin in this ability to index symbols, i.e., to provide them with the shared meaning.

Linguistic knowing is thus potent, but it is also remote from the occurrences about which knowledge is constructed. From these properties stem both the respect with which it is held by those who have tested the rewards of thoughtful analysis and the distrust with which it is viewed by those who prefer the immanence of the laboratory bench to the desk chair.

KNOWING AND MEANING, A NEUROEPISTOMOLOGY

To summarize: The results of experiments performed in my laboratories over the past two decades have led me to believe that the issue central to effective learning and remembering is coding. The nervous system turns out to be a magnificent instrument for efficient coding. The obvious suggestion is therefore that knowledge is a function of the brain's coding operations.

Several sorts of neural coding have been identified. A primitive code is composed of the excitatory and inhibitory interactions among neurons. From these elementary processes Images of three kinds are constructed: Events in the perceptual world initiate Images-of-Events; Monitor-Images deal with feelings; and Images-of-Achievement are concerned with Action. Through Action, Image constructions can yield Immanent Knowledge, personal, immediate and vital. More often, however, the intermeshing of the processes which give rise to Images-of-Events and Monitor-Images on the one hand and Images-of-Achievement on the other, gives rise to Signs and Symbols: Signs when perceptions are acted on, Symbols when action regards feelings. The derived knowledge of Sign and Symbols, though not as immediate, is public and can therefore be communicated readily.

A still more remote coding operation constitutes linguistic knowledge. Man, by indicating the significance of Symbols, indexing, labelling them, can communicate shared feelings. This facility proves to be a potent stimulus to expanding the communicative effort. Man can also make symbolic use of Signs, substituting Symbols arbitrarily until some "fit" is attained either to physical, biological or experiential disposition or through social usage. The power of the logical linguistic knowledge thus achieved is countered by its remoteness from that which is to be known. At its best therefore knowing becomes a web constituted of linguistic, derived and immanent knowledge processes, none of which are sufficient in and of themselves.

Should these views of the coding properties of our nervous sytem prove viable they would validate the main thrust of the argument expressed in Charles Peirce's theory of meaning (Peirce, 1934). Though I have freely used Peirce's nomenclature, my views were initially derived from neurobehavioral and neurophysiological data independently of any thorough reading of Peirce. Thus differences occur in systematic analysis and the uses to which I have put the nomenclature.

Despite this, Peirce's incisive thinking makes a good starting point for understanding. For example, Peirce makes the statement that "we are too apt to think that what one *means to do* and the *meaning of* a word are quite unrelated measurings of the word meaning." He points out that meaning is always related to doing, to the pragmatic in some way. However, he comes to this view in a long and tortuously reasoned argument which leaves unclear some felt relationships between tokens and icons and ends by stating that symbolic meaning is *the* essential form of meaning. In this way of taking on its pragmatic mantle knowing becomes overly expedient. My own analysis appears, to me at least, more straightforward and productive of a more balanced end. The fact that signs and symbols are derived in part through action brings to knowledge the dimension of intentionality, pragmatic but not expedient. Thus, for me, the pragmatic similarity of "what one means" and "what one means to do" centers on the intentionality of all meaning, the fact that significant and symbolic activity is forming, through the brain mechanisms involved in action, a representation of one's Imaging. Even the most abstract efforts of the mathematician concern his vision of relationships he can construct between occurrences. Even the most earthy of symbols, the phallic Hindu lingam, takes its impact from the imagery evoked by the stories of divine powers.

I would suggest, therefore, that both Indices and Symbols derive meaning to the extent that they can be employed to evoke Immanence. As in Peirce's theory of meaning, this gives primacy to an abductive form of reasoning: What I should today call hypothesis formation by analogy as against reasoning by deduction or induction. This is not to deny the importance of deduction and induction—only to deny them primacy.

The logic of abductive inference has received little formal study in Western philosophy. In science, however, abduction is now commonly used and takes the form of modeling. A fascinating example of the proper use of abductive reasoning was displayed by Watson and Crick in their discovery that the structure of DNA is a double helix (Watson, 1968). Careful study of such scientific endeavors should clarify the rules of legitimate abduction and its relationship to induction and deduction.

Until more is known there is little use in speculating about the possible neural mechanisms involved in abductive reasoning in all its complexity. It is likely, however, that because of the freshness of analogy, the novel call it makes on the familiar, the match and mismatch among expectancies, that a good beginning has been made in the study of the elemental processes involving the orienting reaction and its habituation (Bagshaw and Benzies, 1968; Pribram, 1969).

For epistemology the message of my view is clear. We have altogether too long and too exclusively focussed on the logical operations involved in deductive and inductive coding. We have paid only lip service to the external representations which can be constructed from these, and have not faced the key role of intentionality derived from Action in begetting Signs and Symbols. Further, only the intuitive philosopher has allowed himself the license of abduction and then only informally. For we have not clearly recognized abductive coding as a legitimate procedure. According to the analysis presented here, not only are abductive processes legitimate, they become essential if indices and symbols are to be made immanent and thus attain empirical, existential and pragmatic validity.

Ordinarily, in our concern with formal information processing, with rote indexing and with logical symbol manipulation, we have excluded abduction and therefore the path to immanence. On the other hand, immanence, whether empirical, existential or pragmatic, is not by itself, enough either. Though momentarily meaningful, immanent knowing will fail to provide the more enduring consensual ways of knowing unless the disciplines of Indexing and Symbolizing are also cultivated through Action to beget the power of linguistic operations. Knowledge is of a piece, linguistically potent, neurologically derived and beyond all that, Immanent.

SUMMARY AND CONCLUSIONS

The theme has been developed that knowing results from a complex of brain processes that are hierarchically arranged. The brain is so constructed that it continuously recodes signals. The initial recoding operations on input result in images. These are the representations that constitute immanent knowing. One form of immanence is that produced in the motor systems: an image of achievement that readily transforms into action. Acts are public and therefore subject to consensual validation. Thus a second level of knowing is derived when acts represent images of events in the world-out-there and when acts represent images that monitor the world-within-the-organism. These second level representations are here called signs and symbols. At the apex of the hierarchy stands the linguistic process which combines sign and symbol. Linguistic operations give rise to logically definable knowledge. Each level of knowing has its own strengths and limitations.

COMMENTS ON PRIBRAM'S PAPER

J. R. Royce

Let me begin with several comments on why I am impressed by Dr. Pribram's paper. First of all I'm impressed by the scope of his statement. As I see it, Professor Pribram is trying for nothing less than a general neuropsychology—and in this particular paper he puts the spotlight on the epistemological aspects of this general theory. Secondly, I am impressed by the conceptual ingenuity he has brought to bear in dealing with intransigent problems. Take, for example, the notion of coding as the key to knowing, and the hologram as the relevant underlying brain mechanism. Why should we be impressed by such a concept? Because nobody has known how to account for the fact that extensive brain damage impairs performance so little and because a hologram-like mechanism could resolve the dilemma of redundancy in coding. The hologram mechanism says that a small, but appropriate, sampling of the relevant elements is all that is required in order to reconstitute "organized wholes." This kind of concept introduces theoretical order in a domain of study where the pendulum has been oscillating between the poles of localization and mass action for over a hundred years, and if it holds up, it will constitute a conceptual breakthrough of the first magnitude. In spite of this possibility, I am primarily impressed by Professor Pribram's contribution because he is trying to spell out the underlying neurology of *constructionism*, and I must say that is a terribly difficult task. The point is that such an approach constitutes an attempt to get at the heart of the matter, namely the problem of *cognitive representation*, rather than play the more typical, safer, psychophysiological game of simply not bringing in mentalistic phenomena such as meaning, symbols, and image.

Let me now elaborate on what I believe is the heart of Pribram's neuropsychology—his effort to deal with the sign-symbol distinction. I will do this with two purposes in mind: (1) to provide an overall summary of his basic position, and (2) as a basis for asking a question. The summary is given in Table 1.

Now for the question. What is the relationship between your view of symbol and that of Cassirer? I'm reasonably certain your position is not inconsistent with his, but I wonder if you would offer a direct statement on this point. I ask it because the underlying neurology makes good sense in Cassirer's

TABLE 1 Summary of contrasting characteristics of sign and symbol as viewed by Pribram

Characteristic	Sign	Symbol
Type of Coding	Indexing	Symbolizing
Type of Meaning	Denotative	Connotative
Parallels to Peirce	Inductive-deductive	Abductive
Sample Behavior	Discrimination learning	Indirect delayed response
Neural Basis	Primary cortical projection areas and posterior association cortex	Frontal pole; Limbic system

context, and my own view is that Cassirer's (1953, 1955, 1957) philosophy of symbolic forms has not received the attention it deserves by either psychologists or philosophers. On the other hand, your criss-cross usage of sign and symbol on p. 459 was confusing, if not actually incompatible with Cassirer's conception.

There are inevitable problems of clarification—some of them semantic and some of a more conceptual nature. My most serious semantic difficulties hover around your usage of the word immanent. The most relevant dictionary definition of this word is "taking place within the mind of the subject, and having no effect outside of it." Having this in mind helped me at various points in the manuscript, but because I'm not clear regarding its usage, I've missed the full impact of your message in several crucial places. Two good examples are your last sentence in the paper where you claim that knowledge is, above all, immanent, and earlier (p. 455) where you allude to existentialism as one of three forms of immanent knowledge.

My problems with your meaning of "image" are of a more conceptual nature. I believe you have described yourself as a subjective behaviorist, and on top of that it is clear you are a non-reductionistic neuropsychologist. Given that kind of openness, what are the conceptual implications of the term image? Is it purely subjective? Is it merely a neural pattern? Or do images follow some kind of psychoneural isomorphism?

Toward the end of your manuscript you allude to the importance of abduction as a legitimate way of knowing. I happen to share this bias, but I do not see the basis for your claim. Can you elaborate on this? Why is abduction a valid mode of knowing? And why should psychology pay more attention to it?

Finally, a more philosophical issue which you may prefer to leave to the philosophers. As a psychologist interested in the neural basis for knowing, your working definition of knowledge as "codified information consensually validated" is acceptable. But it simply won't qualify as an adequate elaboration of truth criteria. For example, in the section on immanent knowledge you state that "knowledge is known to be true [by] the *effect* such knowledge has," and you point to different effects for the three epistemologies of empiricism, existentialism, and pragmatism. I am not suggesting that we initiate an infinite regress, but that you take us at least one step beyond consensual validation by spelling out the three different types of consensus which are implicit in your position.

DISCUSSION OF "NEUROLOGICAL NOTES ON KNOWING" BY KARL PRIBRAM

Kellogg V. Wilson

This paper is quite compactly written and I found it necessary to reread it several times and to take notes in order to understand it. Since I regard this paper as an important attempt to describe the brain as a macrosystem—a rare phenomena among physiological psychologists—and since this effort is quite consistent with some current trends in cognitive psychology and psycholinguistics, I would like to comment on two points on which I feel some misunderstanding is likely to arise. I do not feel there is any essential disagreement with Pribram's position but that these points deserve further emphasis and discussion.

First, I would like to consider the phenomena of "coding" in terms of formal grammars (Chomsky, 1963 in bibliography of my paper). Roughly, any grammar contains a set of rules for rewriting strings of symbols and so describes a coding operation. In a context-free grammar, the rules for rewriting any symbol are independent of the context in which the symbol appears whereas in a context-dependent grammar, at least some of the rewriting rules depend on the context of a symbol, usually adjacent symbols. In general, the recoding or rewriting operation in computer languages are usually context-free while natural language exhibits strong contextual dependencies—e.g. the exact meaning of a word will very frequently depend on its context which makes language translation based on word for word substitution inaccurate. Also, the Gestalt psychologists have often demonstrated that the interpretation of a particular contour can vary considerably with the context in which it is embedded. Pribram certainly recognizes the importance of contextual dependencies in coding when he states that "Again and again my experiments showed that how much may be learned or remembered— indeed even *what* may be learned or remembered—is at any moment determined as much by the context, the set and setting, in which an informative item is placed as by that item *per se*." Yet his example of recoding of sets of three switch positions into numbers (which is essentially a conversion from base two to base eight representation of a number) is an example of a context-free grammar. Moreover, this recoding is based on rules (which he describes) so that only three rules (plus rules of arithmetic rather than eight) need be retained. This coding is essentially an extension of codes we have already learned as are the mnemonics he cites such as JMP for "jump" and CLA for "clear the accumulator."

My discussion of Pribram's example leads to a kind of apparent paradox. The recoding operations which are easily learned by humans involve mnemonics or rules which are extensions of already learned codes which involve a considerable reduction of the number of associations needed for arbitrarily assigned recoding operations, yet the coding operations involved in perception by the higher animals, at least, and in the use of language by humans seem to involve context dependent coding of a very complex sort. Of course, there are a variety of plausible explanations for this—among them that the recoding operations of language and perception are extremely overlearned in early life (perhaps during a maturationally determined period) so there is a strong predisposition to learn new recoding operations in terms of old ones. However, regardless of the position we take on the resolution of this seeming paradox, we have to introduce concepts regarding recoding operations that go a good deal beyond the more superficial interpretations of Pribram's example.

My second point concerns the use of the term *image* which has an unfortunate similarity to the term *imagery*. The traditional discussions of eidetic imagery emphasized the capacities of some individuals to reconstruct past visual experience in the form of an image so that detailed information, from a printed page for example, which was not initially attended to can be retrieved. However, this holistic kind of coding does not appear to be very common nor is it what Pribram has in mind. He states that Imaging involves "a process in which only a limited number of variables need be coded" and that the components of the code "are no longer the presence or absence (on and off) of neural impulses but are indicators of relationships among them." To me, this implies a considerable similarity to the Quillian type memory system described in my paper in which both properties and relationships are codified. In addition to the possibility of a reconstruction of the environmental event as coded, such coding permits the construction of combinations which have never been experienced, as can be vividly seen in the more creative imaginative play of children, artists and even (sometimes) scientists. Again, this involves no essential disagreement with what Pribram has said and is quite in key with the affective spirit with which he has said them. Insofar as there is disagreement it concerns what I feel is a somewhat arbitrary distinction between Images, Signs and Indices. I think it is correct to paraphrase Pribram as saying that Images are relational codings of experience, that Signs are relational codings of Images and that Indexing involves relational coding of Signs.

For reasons indicated in my paper, the extreme amount of interdigitation of relational codes in the Quillian memory would make such levels about as distinct as boundaries between academic subjects. Symbols may have a special status because of their relations to inner events—e.g. feelings—but I expect they are involved in this interdigitation as well. The assumption that a Quillian memory organization is as general as I have assumed may seem unwarranted, but it is more general than the hierarchy Pribram implies and it is a plausible model for a relational code involving discrete elements.

COMMENTS ON PROFESSOR PRIBRAM'S PAPER

William W. Rozeboom

There are few academic sports spectaculars quite so exhilarating as the sight of playmaster Pribram finger-tipping the ball in full sprint downfield. Yet if the game is not to degenerate into a shambles, someone must take responsibility for blowing the whistle on fouls.

Actually, my whistle chirps here will be rather timid, for while I have deep suspicions about much of the action in Pribram's performance, it all happens too fast for me to tell exactly what is going on. According to Pribram, the general sequence of cognitive events in an organism is for stimulus input to be first *coded* by the nervous system and then recoded into patterns of neural activity called *Images-of-Events*. Meanwhile, internal physio-chemical conditions give rise (via coding?) to *Monitor-Images* while images of a third kind, *Images-of-Achievement*, are representing *Actions* (i.e., external accomplishments). When these images-of-achievement interact with images-of-events on the one hand and with monitor-images on the other, *signs* and *symbols* respectively result. Finally, linguistic knowledge results when "man manipulates Symbols as Signs." All of this seems very profound—too much so, unfortunately, for me to understand very clearly. I do, however, find myself noting possible inconsistencies and wondering if Pribram has really addressed the definitive issues of cognition.

His theory of action, for example: I think I am safe in construing this to be very similar to Metzger's account (p. 244ff. above). Certainly Pribram's statement that "Images-of-Achievement guide movement ... by tuning the reflex" (p. 455), i.e. that these set the equilibrium points in homeostatic lower-level motor processes, well fits this conception. But then I am at a loss to interpret his claim that images-of-achievement "are composed of signals [from muscular force fields] initiated by forces external to the organism" (p. 455), for this seems to imply that the reflex tuning so brought about is determined blindly by the organism's recent history of muscle events rather than by superordinate control from his cognitively intended goals. Very likely a simple rephrasing or word of clarification would allay my doubts on this point (as the final draft of Pribram's paper has already done for certain other qualms I had originally raised here). Considerably more than that, however, seems necessary to make public the substantive insights which I trust underlie the pyrotechnic dazzle of Pribram's account of cognition's afferent stages:

Consider, for example, his concept of "coding". Does this have any *psychological* implications beyond recognizing the obvious fact that since neural propagation of input signals cannot literally copy physical events at the receptor surface, central sensory processes must be transformations of their input precursors? I grant that Pribram is working towards a specific theory concerning what aspects of CNS activity are correlated in what way with input patterns, but he hasn't suggested what import this may have for a psychology which abstracts the functional properties of cognition from its neurophysiological substratum.

Again, we are told that the first stage of neural coding passes over into images[-of-events] through "a further coding process by which the neural process can represent fully its origin," (p. 453). I am unsure whether this is meant to imply that the pre-Image stage of coded input does not represent its origin as fully as does the Image, or merely that the two coding stages both fully represent their origin. Either way, Pribram's claims about "representation" remain gratuitous at best (and beguiling at worse) until he clarifies what sort of representation is at issue here and faces up to the more important logical problems which remain for his account in this sense of the term. Does he really mean just that variable X "represents" variable Y when X-events are isomorphic to or statistically correlated with Y events? If so, then the Image can represent its origin no better than does the pre-Image stage of coding (since when the relation between variables X and Y is mediated entirely by variable(s) M, Y can be no more highly correlated with X than is M and will be less so if there is any error variance in the system); while by virtue of the reflexivity, transitivity, and (more roughly) symmetry of isomorphisms and correlations, the Image, pre-Image, and environmental origin all mutually represent one another as well as—most accurately of all—themselves. Surely Pribram intends "representation" to be more selective than this, so that an Image represents its external source *rather than* (instead of in addition to) itself or the pre-Image Coded input. Surely in an essay whose theme is the epistemic act of knowing and which purposefully makes free use of classical psychology's major cognitive concepts, the *of*-ness ascribed to Images-of-Events is intended to be the *cognitive* relation whereby an image Y represents an originating event (or between-event relation) X when Y is referentially *about* X. But then which among the events (or relations among events) in the causal sequence leading to Y is the one that Y represents, and by what analysis of aboutness can it be claimed that Y represents *that* particular X rather than some other one of its causal precursors? For example, if a photograph presents a viewer with retinal stimulation that arouses first-stage coded neural activity which in turn produces a recoded Image, is the originating event represented by this Image (1) the pre-image neural coding, (2) the retinal pattern, (3) the configuration of pigments on the photographic print, (4) something in the negative from which the print was made, or (5) the original scene to which this negative was first exposed? If Pribram elects (3) or (5), as I hope would be his preference, on what grounds can he argue that the viewer's Image represents the distally external event rather than its retinal or post-retinal consequence? Since he speaks of "resemblance" several times in this context, would he propose that the Image is literally more *like* (i.e., similar to) its distal origin than it is like mediating events at the sensory interface?

I am similarly uneasy about Pribram's treatment of "signs". We are told that these are produced by "decoding" or "indexing" images-of-events by much the same mechanism that produces images-of-achievement. Just how this occurs is not clear to me, for at one point (p. 456) the achievement-mechanism produces signs by modulating receptor action, which would control which images-of-events are formed in the first place rather than how the latter are subsequently Indexed; later, however, it is said that indexing "derive[s] when Images are Acted upon" (p. 459), while the "interdigitating" of images-of-events and images-of-achievements sounds more like an amalgam of these two image types than like a receptor bias on the first. But more important is what Indexing is conceived to accomplish. I interpret this to be a categorizing (*á la* Bruner) of images-of-events, that is, an abstractive identifying of their distinctive features. For this to be a genuine cognitive operation, however, the Image must have its identified attributes predicated of it in a propositionally structured process; whereas so far as I can make out, Pribram's Signs are simply reactions (central or otherwise) elicited by the Images so indexed. If so, his account of sign processes is nothing more than a neurophysiologically flavored paraphrase of traditional association-theoretic models (*á la* Staats and Kendler) which treat concept formation, abstraction, judgment, and other cognitive phenomena as convergent associations, i.e., as common labeling responses becoming attached to a variety of stimuli. I know Karl well enough by now to feel sure that he has something considerably more interesting than this in mind, but what that something-more may be remains at present a tantalizing mystery.

Pribram's use of the word *Symbol* to denote those "expressions of feeling" which derive from classifying Monitor-Images is strongly at odds with what most philosophers understand by this term, but I suppose that he is keying into the usage under which "symbols" (i.e., the Flag, Hamlet-seen-as-Everyman, firearms-seen-as-phallic, etc.) have an artsy-gutsy subjective/existential orientation *contra* the semantically pure external outlook of "signs." But are hormonal balances and the like then "the events [which symbols] symbolize" (p. 459)? If so, what is the nature of the relationship by which an indexed monitor-image is a symbol *of* a hormonal event? (Pribram emphasizes that it is not an isomorphism, but what then *is* it?)

Finally, to lessen the prospect of rotary agitation within Charles Peirce's grave, a *caveat* should be filed against the view that for Peirce, *abductive* reasoning is hypothesis formation by analogy (a claim which Pribram has now softened considerably since his original presentation but still not entirely abandoned). Peirce used the term "abduction" to describe whatever processes are responsible for a person's first thinking of a hypothesis prior to its subsequent confirmation or disconfirmation in one way or another (see Peirce, *Collected Papers* Vol. VI, p. 358). "Analogy" for him was a form of inference which *contrasted* with reasoning by hypothesis, while "abduction" was an aspect of the latter. In his own words,

> Argument is of three kinds: Deduction, Induction, and Abduction (usually called adopting a hypothesis). (*Collected Papers* Vol. II, p. 53.)

Peirce's concept of "argument" is broader than that of "inference," for it includes the acquiring of hypotheses in ways other than inference, namely, by abduction:

> Abduction must cover all the operations by which theories and conceptions are engendered. (*CP* V, p. 414)

For deriving conclusions from premises, on the other hand,

> non-deductive or ampliative inference is of three kinds: induction, hypothesis [whose premises may be given by abduction], and analogy. (*CP* VI, p. 31),

while

> analogy ... is a type of inference having all the strength of induction and more besides. (*CP* V, p. 411; the logical form of analogical argument is given in *CP* II, p. 310.)

Since Peirce treats analogy as distinct from though similar to induction, he should probably have included Analogy as a fourth kind of argument in the first quotation above.

REBUTTAL TO DISCUSSION

Karl H. Pribram

Back at the Center for Advanced Study in Theoretical Psychology I write this rebuttal to my three sometimes devastating and often insightful discussants just two years after my initial visit and one year to the day after my arrogant foray into neuroepistemology at Banff. I am, of course, grateful for the valiant attempts each of you made to have me become understandable and for "blowing the whistle on fouls." Let me, in this spirit of gratitude indicate in three separate sections (Sign and Symbol; Images; Ways of Knowing) the direction my thinking has taken over the past year and then, from this point of departure, to answer to the best of my present ability the specific questions posed.

SIGN AND SYMBOL

I begin with Kellogg Wilson's contribution. The heart of it concerns his statement that: "In general the recoding or rewriting operations in computer languages are usually context-free while natural language exhibits strong contextual dependencies ..." Wilson has spent his sabbatical this past year in my laboratories pounding away at this idea that we must distinguish between context-free and context-dependent constructions. He finally got through to me when with sudden insight while preparing another manuscript (What Makes Man Human, James Arthur Lecture, American Museum of Natural History, 1970) I realized that what I call signs are characterized by their context-free construction and that what I call symbols are characterized by their context-dependency. A sign is a deictic, denotive, indexing of events imaged. A monkey mastering a simple discrimination task learns that a + sign means peanut irrespective of the location or other stimulus dimension in which the + sign is embedded. In fact, learning to make discriminations or learning to make signs (as has Washoe the chimpanzee who communicates by means of American Sign Language) is to establish a context-free code.

Symbols, on the other hand, derive from context-dependent constructions. The delayed alternation task is the simplest example in primate experiments: Whether a monkey is to open the right or the left of two adjacent cups in order to obtain a reward is dependent on the context of where he had obtained the reward on the previous trial. In the delayed reaction task, the appropriate response is dependent on the context signalled during the predelay period. As an extension of the delay task, a hierarchy of contexts can be established in which each signal or reward becomes a token that establishes the context for the subsequent action. This is what was done with the Chimpomat during the 1930's and is currently being exploited by Premack with his chimpanzee Sarah.

Neurologically it makes sense that signs as context-free organizations are constructed by the activities of the primary projection systems and their associated areas of intrinsic cortex. Discrete, well structured, and fitted for a great deal of parallel processing, these systems allow the sorting out of constancies in the transformation of input. By contrast, the limbic systems of the forebrain are built with multiple self-reflecting loops within loops—just the sort of anatomical structure necessary to set up the sets of recursive functions necessary to the context-dependent constructions characteristic of symbols. Neurologically speaking, context dependency becomes state-dependency where state is a more or less temporary memory or motive setting. Thus, using the letters of the alphabet as signs is done when an index is made; using the letters of the alphabet as symbols occurs when words are made.

I believe that this modification of my earlier analysis of sign and symbol meets some of the difficulties encountered by my discussants. The use of the term symbol especially was obscure—now it falls more nearly in line with the usage given by Susan Langer and perhaps Cassirer and also, to some extent, Morris. I still differ with all of these earlier usages, however, in giving equal independent and parallel weight to the construction of sign and symbol and reserving for propositions the process of bringing the two together. In this respect my analysis is somewhat akin to that of Ayer's (1946). Thus, in direct answer to Kellogg Wilson's question, I think that hierarchies of signs are constructed by rewriting rules similar to those employed in computer languages and set forth in *Plans and the Structure of Behavior*; that hierarchies of symbols, on the other hand, are made more along the lines of a Quillian construction. Language uses both and this has given trouble in analysis. Nonetheless linguists and psychologists have felt the validity of the distinction. Psychologists have conceptualized it in terms of the difference between long-term and short-term memory (e.g. Atkinson, Bower); linguists in terms of the dimension simultaneity and successivity (e.g. Jacobsen).

Pribram	*Psychologists*	*Linguists*
Sign	Long Term Memory Process	Simultaneity
Symbol	Short Term Memory Process	Successivity

IMAGES

A second group of questions concerns the relationship between Image and the Neural Hologram. Here I can do less in the way of clarification since the issue runs squarely into the mind-brain problem. I have discussed my views on this issue extensively in the final chapter of *Languages of the Brain* (1971). Briefly, in reference to the present manuscript, the interpretation of what can be meant by the term Image depends on one's stance in the mind-brain dilemma. A monistic-pluralistic stance would either identify the brain process of neural hologram formation with Image formation or would point out that these are two ways of talking about the same set of events. The dualistic stance would suggest either that Images occur in parallel to neural holograms or that they intervene between the neurological process and subsequent related behaviors. Each stance has deficiencies and as a biologist I am awed, continue to wonder, and simply accept the mystery of the fact that I do perceive images which are altered when my brain processes are messed up.

I do so hope that my answer will be adequate to the questions posed by both Rozeboom and Royce, for I feel it important that science get away from a "know-it-all" attitude. There is a point at which analysis can go no further—the alternatives are adequately spelled out—and we can sit back and enjoy the mysteries of the natural world. I do not, of course, mean by this that we should be slovenly or slothful; nor do I mean by mystery some hazy shroud with which to envelop an issue. Quite the contrary. The feeling of mystery comes to me from having pushed hard-nosed analysis to its extremes and thus sharply illuminated the complementary facets of a complex issue. I am not claiming that I have reached this point in our discussions of Image, but I think sometimes there is a hidden agenda of a search for complete and absolute certainty when questions are asked in psychology, an agenda long ago given up when questions in physics are considered.

Given this framework, perhaps Rozeboom's and Royce's questions about the relationship between Images-of-Achievement and Images-of-Events can be answered, and also their more general query about the role of representations, internal and external. Taking the dualist stance, I would say that in writing this paper which you, Royce and Rozeboom can read, I have made an external representation of the neural process involved in my Images-of-Events over the past years. I have been able to do this by virtue of another set of neural processes—those which are involved in Images-of-Achievement. These neural processes have made it possible for me to write words and sentences with a pen on paper and to correct these scribblings until I have achieved a readable manuscript. The Images-of-Events and Images-of-Achievement on the one hand and the neural processes and this manuscript on the other, constitute two worlds—one private, one public (i.e., communicable), and both concern the scientist. There is a different and perhaps simpler and less provocative interpretation if I take a monistic-pluralistic stance: I would now claim that my brain states, this manuscript, and the final printed chapter are all embodiments of the same sets of experience I have enjoyed over the past years, experiences completely specifiable in terms of my observable interactions with the discussants and with others through talking and reading and writing.

The virtues of the multiple realization stance are obvious. Analysis is limited to that which is observable. A hard-headed precision and clarity can be achieved. What is sacrificed, however, is the intuitive reach of problems generated when the private world of experience is addressed independently and directly. For example, if the mechanism of pattern recognition is analyzed in terms of observables, the appropriate behavior can be generated to some considerable extent by a system of feature extractors preset to do the job. Actual human pattern recognition, on the other hand, is accompanied by a richness of Image unnecessary to the achievement of the recognition response. A decision must be made as to whether to ignore this richness. At times, for the purposes of simplicity and rigorousness, I am willing to temporarily shelve the problems posed by the private world. But over the long haul, as a psychologist, especially as a physiological psychologist, these problems must be faced in their own right for they are what make man human. And I am vitally interested in what constitutes the difference in man's brain that makes the difference.

WAYS OF KNOWING

Most of the remaining questions posed by my discussants refer to forms of knowing. Royce clearly formulates these questions in terms of the necessity for consensual validation and truth statements; Rozeboom centers his queries on my use of Peirce's term Abduction. In my paper I make the distinction between knowing and knowledge. I want to hold to that distinction. Knowing can be a private affair; knowledge is always public. In discussing this matter at length with Royce we came to the conclusion that when knowing is primarily dependent on Images-of-Events (percepts) and Monitor Images (feelings), the term "authenticity" is more appropriate than "truth." These forms of knowing I have called "immanent" and the definition given by Royce in his discussion describes what I mean. Immanent knowing is personal, private and may be difficult to communicate. Thus the criterion for knowing in the empiricist and existential modes is authenticity not truth.

The pragmatic mode, also, has nothing to do with truth. To know how to act is to be able to achieve the action. Achievement is the criterion for knowing. Knowing through achievement is partly a public and partly a private matter. One may look to others to determine (through extrinsic reinforcement) whether one has achieved or one may examine the match (intrinsic reinforcement) between act and intent, between the external representation achieved and the pre-existing representation of the Plan-for-Achievement in the Images-of-Achievement.

I believe from what I have so far learned from philosophers at this conference and from my readings since, that truth as a criterion for knowing comes in only when propositions are made. I use the term proposition to indicate constructions made by man when he uses signs symbolically, i.e., when he uses signs in a context-dependent fashion. This context dependency is, however, restricted and consistent. The context is predication, i.e., the truth or falsity (lawfulness?) of the way in which the sign is used. Thus the word boy may be used as a sign; the statement "this is (is not) a boy" can be taken as a proposition declaring "knowledge" which is potentially verifiable. Much of man's scientific effort is devoted to statements of procedures for verification.

In a similar manner, man uses symbols significantly. He does this when he reasons. Reasoning is accomplished by adopting temporarily a set of arbitrary rules which dispense with context dependency and thus momentarily free symbols from their ambiguity. Algebra or geometry are examples of "pure" reasoning.

Induction and Deduction are readily identifiable forms of reasoning as pointed out by Rozeboom. His question concerns abduction and the relationship between metapohr, analogy and abduction. My own view is that these terms denote a continuous dimension along which metaphor is the least, and abduction the most precise. Today we call abduction "model construction." Metaphor calls forth a feeling (Monitor-Image); analogy evokes a percept (Images-of-Events); and abduction, as I want to use the term in its present day model building definition, makes its demands on action (on the Image-of-Achievement). Since Peirce did not distinguish between types of Images, my usage of "abduction" differs from his but I believe that it is consistent with the spirit of his usage: As Rozeboom points out and substantiates in his quotations from Peirce, abduction gives rise to hypotheses, it is not directly involved in the reasoning process itself.

However, others might be less constrained in their use of the term reason—Wittgenstein for instance, points out that we rarely proclaim that an incorrect mathematical proof is unreasonable.

This is about as far as I now dare venture into the problems of the philosophy of knowing. The stimulus provided by the Center over the past two years has revealed a challenging vista, a world populated by neurophysiologists, traditional psychologists, behaviorists, cyberneticians, logicians and traditional philosophers. Perhaps I have as yet poorly identified just who is who, but, does this really matter so much? Though a search for how "who" knows may give direction to the search, the primary question does remain "how do *we* know?"

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