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ABSTRACT

Cognition, not to be confused with perception, reception, or stimulus detection, is defined as relationships of sensory experiences in single-loop matrices. The reticular system of the upper brain stem is centered upon as the likely locus of sensory filtering and modification that can modulate language usage. That is, higher cognitive functions are affected by the reticular matrices. Using an auditory input model, primarily, it is demonstrated that frequency, phoneme, and morpheme matrices are affected by the abductive logic of the reticular system studied. It is concluded that "language cognition is a probabilistic process of hierarchical matrices each responding holographically when matrices of the next lower level cumulate sufficient energy to activate them." (CH)

LANGUAGE COGNITION: A THEORETICAL MODEL BASED ON NEURO-CORTICAL MATRICES

By Don George

Our existence may be described as being proscribed by an expanding and expansible sphere. This is our known world. Outside this known world lies the vast unknown, and even our wildest imaginations cannot begin to comprehend its magnitude, for awareness of the unknown is limited by the dimensions of the known.

As we press our eyes against the boundary of our knowledge we dimly see small portions of the unknown, and we ask questions about what we think we see. As we collectively press outward to find answers, the confining walls of our knowledge expand, only to leave us nearer to other dimensions of the unknown about which we must ask more questions and seek more answers. As we are all looking into this unknown through different windows, we do not all see the same things, nor do we ask the same questions about what we think we see.

This paper does not propose to give a final answer to the questions about language cognition. It merely tries to push out into one aspect of the unknown and ask, "Is what I think I see really there?" For any who would say, "I don't see what you claim to see," I can only suggest we may have been looking through different windows.

First let me define the term cognition as it is to be construed in this discussion. Cognition is not to be confused with perception, reception, or stimulus detection. Pribram suggests, for example, that feature detection, which is implied in such terms, involves

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elements which are built into the neural apparatus, stable and unmodified by experience. They may be said to pre-process signals before other operations are performed. Cognition, on the other hand, involves relationships. This is indicated in the etymology of the word. From the Latin prefix co-(together) plus nosco (derived from Greek gnosis, meaning knowledge) we define cognition as the integration of two or more sensory experiences into a single loop matrix. The re-stimulation of any part of the matrix will reactivate holographically the previously established loop.

We should distinguish cognition from recognition. The process of establishing an interlaced matrix from two or more sensory input matrices into an identifying pattern is cognition. The re-activation holographically of such a matrix at a later time is re-cognition. More will be said about this later.

The question now becomes, how does such an activity function, and what are the apparent loci for such function? Penfield's emphatic conclusion that the cortex is not the center for such integration, and that input to the various sensory areas of the cortex are routed inward to a sub-cortical region, is supported by Gastaut. Gastaut proposes that sensory signals converge in a subcortical area from which they are re-distributed in a devergent way to the cortex. Evidence by Jasper, Magoun, Madge and Arnold Scheibel, Livingston, and many others indicate that the reticular system may furnish the key to this organizational operation, and hence to the process of cognition.

In referring to the reticular system I am particularly indicating that part of the system in the upper brain stem. The reticular system has generally been only cursorily considered in most texts concerned with the neuroanatomy of speech. It might be well, therefore, to give a brief, though somewhat simplified, description of it based on such knowledge as we now have.

Nauta and Kuypers describe the reticular formation as "a neural apparatus receiving a massive influx from several sensory systems, and in turn projecting upward to the diencephelon and thence to the cerebral cortex."

Madge and Arnold Scheibel describe the reticular system as analougous to a stack of poker chips, with axonal connections within each layer, with ascending and descending connections to other layers, with axonal branchings reaching three dimensionally in every direction and even forming junctures with other axon branches and dendrites from the same neuron, with connections with each of the sensory organs at the level of the first synapse, with potential interaction with thalamic neurons before ascending to the cortex, and with a network of non-specific connections ascending to and descending from various areas of the cortex. Cortical connections from the reticular formation are described as ascending in a columnar manner, branching three-dimensionally, with specific areas of the cortex sitting atop each column.

Pribram describes the structure as "felted." The complex axon and dendrite structures appear to stream into each other's field of interaction quite indiscriminately. The Scheibels concluded that under proper physiological conditions". . .an impulse can probably describe any conceivable path within the reticular formation, so extensive is the inter-connectivity of the elements." (One calculation estimates that within two centimeters of length the area of potential interaction of a single axon may involve over 27,000 different cells.)

The reticular formation does not appear to maintain specificity so much as it functions to integrate and direct a number of inputs (Scheibel). Collaterals from primary afferent pathways into the reticular core can affect the unspecific sensory system by exciting reticular neurons. These intricately connected multisynaptic relays thus furnish the integrated impulses for activating the cortex (Lindsley). Though the reticular formation also relies on information which is relayed to it from all sensory areas of the cortex by way of the descending fibers (Penfield), it maintains a control function, and ". . . has never relinquished its central command function to the cortex." (Kilmer) The interaction and convergence of the specific and non-specific connections in the reticular formation".... allows adequate adjustment of cortical functions to the actual situation . . ." (Jung).

Perception, association, awareness, and all cognitive functions occur during a state of arousal or attentiveness. It has been long established that the reticular formation is involved in this state. However, Jung claims, "The function of the brain stem reticular formation cannot be seen mainly under the rather vague concept of regulation of consciousness and attention." Livingston states, "Not only does the reticular formation affect consciousness, . . . it also appears to alter the content of consciousness."

That the reticular system may be considered the site of cognitive activity, as we have defined it, is further suggested by Kilmer and his associates, as "For only its computations are wide enough (have enough scope) to encompass the crucial information in every eventuality, and also shallow enough (do not have too much logical depth) to always arrive at a modal decision within a fraction of a second, given sufficient information."

From the foregoing we may conclude that the intricately crisscrossing fibers of the interconnected layers of the felted reticular formations of the upper brain stem would have the capacity to furnish the sort of cross-indexing of information from multiple sensory stimuli arriving at approximately the same time.

Absolute simultaneity should not be ascribed to any sensory input. The apparent simultaneous perception from any sensory system may be analogous to the apparent holistic picture on a TV screen, though we know the individual phosphors in the tube are activated by a rapidly moving linear scanning.

The anatomical substrate of the neural microstructure is the neural juncture itself as a unit, no the neuron. Slow potentials arise in this microstructure whenever a neural signal traverses the synaptic membrane. This produces conformational changes which are momentarily stabilized as an electric polarization of the microstructure, including the surrounding meuroglia. (Pribram) This polarization holds for a brief period, and the pattern of dipoles provide a holographic matrix for the input stimulus. Since these conformations slowly fade, they form the matrices for what we call short-term memory. In the upper left of the Model I have indicated this as a "hold state" of cumulation matrices for three levels of auditory activity. (See Model)

Even though a complex sound wave appears to be one sound, it is actually a linear sequence of pressure differentials which activate the hair cells in the cochlea at different places, and at temporally discrete intervals. This is indicated as the F-matrix, in which the sequence of a . . . n frequencies is held pending the arousal of additional F-matrices. These are identified, as I suggested in a previous paper, on a match and non-match system based on pattern congruity.

Identification of the components of an F-matrix as matching the phoneme structure of the language sets this matrix up as a P-matrix, or phoneme matrix. Though each P-matrix may vary in its individual characteristics from time to time and from person to person, each will maintain certain elements which do not appear in the same configuration in other P-matrices, and will, therefore, contrast with them.

We are all aware that when we talk about segmentals and suprasegmentals as though they were isolated entities we are doing so merely as a convenience. Phonologists may have a referent for and a cognition of an individual segmental phoneme, but in language a phoneme has significance only as it is placed in a context with other phonemes. The combination of phoneme matrices thus fall together into the first unit of structure, the M-matrix, or morpheme cluster. This matrix unit is perceived in the cortex as a language unit.

At this point the reticular system may intervene. Note the line in the model descending to a cross-hatched square labeled

Fn matrices. This indicates the non-language frequencies of sound also entering the auditory system. They feed into the reticular system, and are gated en route to the cortex as to be ignored (-) or attended (+). These ascending axons also monitor the output from the M-matrices, passing or inhibiting passage. Even if impulses from the M-matrix proceed to the cortex, we still do not have cognition, only reception. Penfield believes the pattern of travelling potentials entering any sensory area of the cortex passes on inward to a sub-cortical target, in this case, the reticular system. Livingston hypothesizes that in a new learning experience a large number of fibers and cortical neurons may be involved, but in familiar patterns they may reduce to a small number of impulses representing an abstraction of the whole. This could account for the apparent slowness in processing an unfamiliar morphological structure as contrasted to the speed with which we process the familiar.

But language cognition includes more systems than the auditory. In the center I have indicated an indefinite number of other sensory systems. Before any language element can be cognized it must have a referent. This is established by conjoining the matrix of the auditory input with one or several matrices from other sensory systems, which I have labelled S-matrices. For example, as we hear the name for an object and visually perceive the object to which the name is applied we generate an interlocked matrix composed of an auditory matrix and a visual matrix. The same would be true with any other sensory connections. This is the first level of cognitive matrices. This matrix may be expanded be reinforcement from additional sensory systems before becoming integrated into an understanding sufficient to decide a mode of behavior.

Since many fibers from the reticular system ascend to the cortex by way of the thalamic region, which many assume to be associated with the generation of emotional tone, the output from the cognitive matrix may, though not necessarily, have additional input from an emotional matrix before reaching the cortex. I have also indicated a gated connection between the reticular system and the cortex which directs whether overt activity in the motor control cortex is to be stimulated or inhibited, since "the electrical activities of the cellular matrix of the cortex are in some degree under reticular control." (Lindsley) (also see Kilmer et al. and Livingston)

Finally, I have included a feedback chain from the sensorily perceived behavior to both the auditory system and the other sensory systems. The dotted lines from the S-matrices and the auditory area to the motor control cortex are intended to show a simple stimulus-response behavior without involving cognition.

In discussing language, however, it is not enough to consider merely how a cognitive matrix is formed from the network of interconnected sensory matrices. We must also consider how, once such a cognitive matrix is established, it will continue to process language information in the absence of some or all of the sensory matrices which entered into its original formation.

Kilmer and his associates, in developing an electronic model of a part of the reticular system (which they designate S-Retic), concluded that such a system must perform abductive logic rather than inductive or deductive. He states, "Its scheme is to go from facts and rules to cases: i.e., facts of sensory and internal perception as represented over the RF input channels, and rules for deciding on the organism's mode of behavior as a function of the RF's ability to classify its immediate environmental stimuli, to cases." The rules are slowly and continually programmed into the system by establishing long-term, or relatively permanent, cognitive-memory matrices.

Short term memory has been described as a process of temporary polarity changes. Long term memory may result froma growth of neuron fibers (Pribram) in chemical changes in the membranes at the synaptic junctures (Hyden), by permanent changes in the macromolecules in the neuroglia (Schmitt), or perhaps by a combination of all of these. There is strong evidence from Lashley's experiments that memory is not a function of any localized area of the cortex. Penfield believes however, that the nervous tissue which preserves memory is a pathway "of synaptic and ganglionic facilitations which linger on after present experience has passed." This preservation of perceptions is utilized in interpreting any present experience. This memory matrix is functionally separated from other processes of intellect. (Penfield)

It would be possible to infer from Lashley's experiments and Penfield's observations that the memory matrices may be a function of the reticular formation. Kilmer seems to treat it as such in his model.

Pribram suggests an interesting concept that the chemical and electrical changes in surrounding neuroglia may stimulate cell division, and that the growth cone of the neural fiber is thus able to penetrate between the two daughter-cells and form further connections with other fibers.

At any rate, the particular conformation of the matrix formed by this increased interconnectivity depends on the past history of these modules; how their alignment has been affected by previous sensory experience. This alignment is viewed as providing a reference connection such that activation from any one of several inputs sets off a chain of connections illuminating the matrix holographically so as to produce a "ghost" image previously associated with the matrix. (Pribram)

But no matter how or where the memory-matrix of increasingly interlaced sensory matrices is formed, it is sufficient at this time to consider that it is. Within the complexity of every cognitive matrix there are context loops which function in a similar, though more complex, fashion as the phoneme matrix. That is, each context loop of the matrix contains elements which both place it in a category and contrasts it with other categories. Thus, language cognition is a probabilistic process of hiearchial matrices each responding holographically when matrices of the next lower level cumulate sufficient energy to activiate them.

The effect of the process flow of multiple cognitive matrices upon the cortex is beautifully pictured by Herbert Jasper in these words:

"Swiftly the head mass becomes an enchanted loom where millions of flashing shuttles weave a dissolving pattern, always a meaningful pattern, but never an abiding one."

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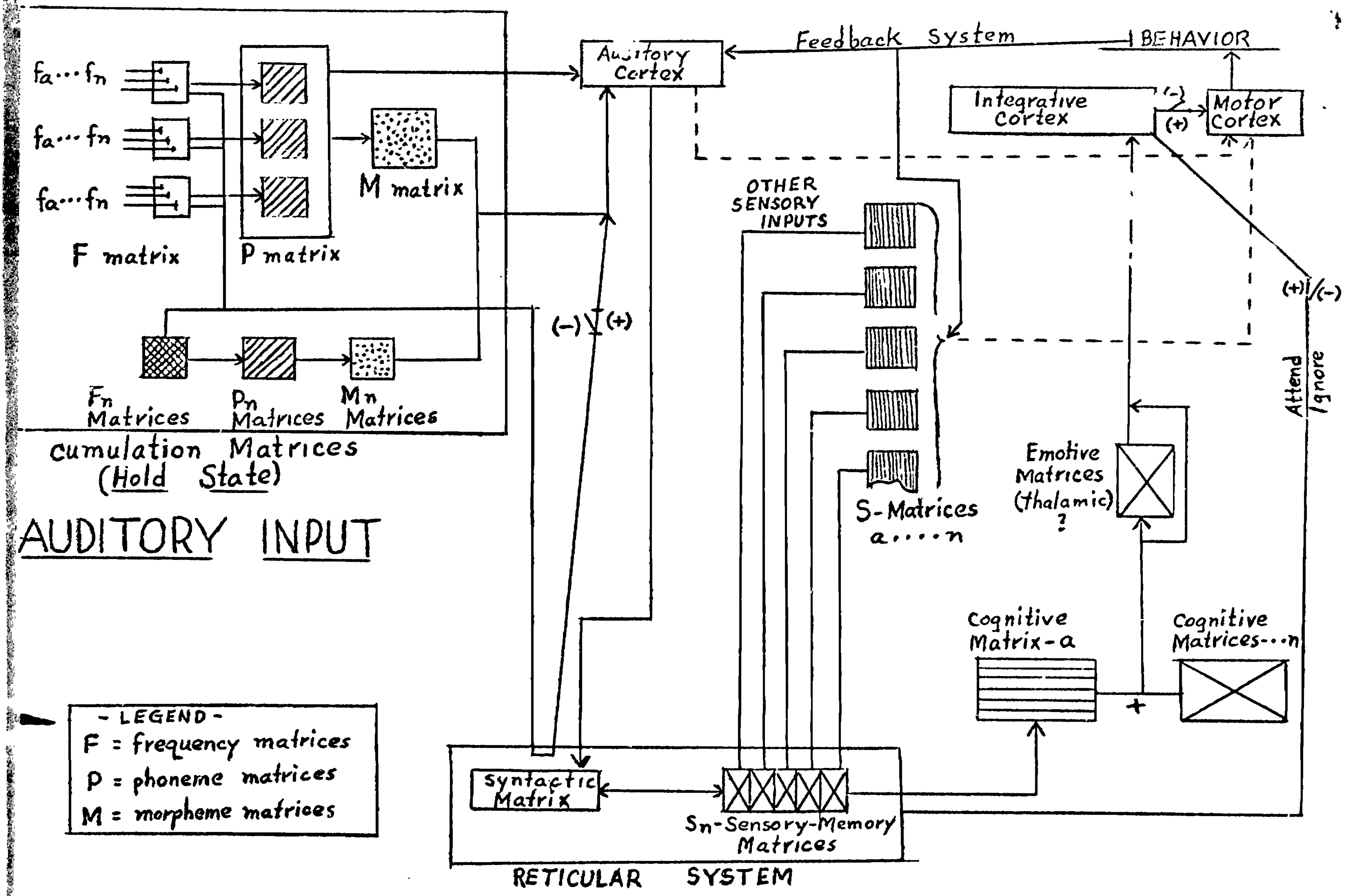
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M matrix
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Pn Matrices
Mn Matrices
Cumulation Matrices (Hold State)
AUDITORY INPUT
Auditory Cortex
Feedback System
BEHAVIOR
Integrative Cortex
(-)
(+)
Motor Cortex
OTHER SENSORY INPUTS
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F = frequency matrices
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M = morpheme matrices