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Second Commentary: On the proper treatment of connectionism
by Paul Smolensky (1988), in
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Neuromachismo Rekindled

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Paul Smolensky's marvelous neologistic epithet "neuromacho" should not be allowed to drift into oblivion. Hence I come forth under the banner of neuromachismo to challenge his assertion that chaotic dynamics is relevant to smell in animals but not yet to speech in humans. Is there such a gulf between olfactive lagomorphs and talking people? What is the difference between a rabbit expressing its love of carrots by rhythmic chewing and sniffing and Prokoviev expressing his love for three oranges in a suite of tones? On the phylogenetic scale these are virtual twins, much as Smolensky's theory and that of Skarda and myself (1985, 1987) are so alike that we can usefully correspond.

The theory of chaotic brain dynamics may prove to be useful in linguistics at two levels. It provides in the immediate present for a framework in which to describe dynamical systems in flux, and it helps us to appreciate the larger impact of chaos theory on literature and philosophy.

Language, like any other form of behavior, is a dynamic flow of meaning, so it may be instructive to hold side by side the known dynamics of odor processing with a hypothetical schema of speech, where "odor" denotes the percept and not the chemical "odorant".

The perception of an odor begins not with the delivery of an odorant stimulus but with an act of searching. It is initiated in the limbic system (Freeman, 1989a), by the issuance of a motor command to inhale through the nose, and by the simultaneous transmission of refference instructions to the sensory cortices along the centrifugal pathways. Odorant molecules that fall thereafter on the olfactory receptors with which they can bind initiate cascades of electrochemical operations. The action potentials that arrive in the cortical mantle activate tissue that has been prepared and sensitized for their arrival. The neural machinery is set a hair's breadth from bifurcation. In the now classic description of chaotic systems, the cortical mechanism is primed to undergo a global state transition in response to a microscopic trigger.

A choice is made, by which an activity pattern emerges over the whole of the sensory structure in the twinkling of an eye. The shape of the pattern is selected by the stimulus, acting as a kind of release, from among an extended array of classes of latent patterns. Alternatively seen, the excitatory bias that is engendered by the stimulus confines the trajectory into a wing of a global chaotic attractor, that has been shaped by learning

(Freeman, 1989b). Belonging to a class, a pattern shape is never twice identical, yet it suffices when transmitted to other cortices to trigger the formation and selection of spatial patterns of activity in those as well. A loop is closed upon the transmission of cortical patterns back to the limbic system, where the initiating patterns of activity are updated, and new commands and refference instructions are issued.

Much of this scenario is documented, and more of it is inferential, but it is complete in describing the dialectical process of interaction of a brain with its environments. Actions and sensory action patterns are repeated stereotypically, yet always with variations both erratic and evolutionary. In point of fact the process is best viewed in the context of goal-directed search in the flexible and adaptive use of odorant molecules to find food or avoid predators. As observers we are free to structure the process into the constraints of classical or operant conditioning, thereby conceptually to impose a stimulus-response sequence on what continues to evolve smoothly and continuously in a form of conversation between subject and scientist, but we are not required to do so.

Similarly an act of language begins as an instance of meaning in the limbic system ("I am hungry", "I want your sex", etc.) that issues as a space-time pattern of motoneuron discharge and muscular contractions (is it so much more complex at this level than an act of sequential sniffing?), and as the priming of sensory systems with refferent instructions (these are equally

unknown in audition and olfaction). Even in laboratory conditions of stereotypy such simple statements vary with repetition, both unpredictably and by evolution, each instance modifying the next that follows. Indeed this is crucial in the immediate follow-up, which is self-monitoring and modulating, hearing the self before anticipating and registering the expected consequence of the utterance, the delayed sensory return from abroad. Both close back into the limbic system in preparation for the next action-reaction sequence.

The spatial neuroelectromagnetic concomitants of the cortical activity patterns in speech genesis and reception have not been mapped as yet, as they have been in olfaction, and there is no guarantee that they ever will be, such is the complexity of accessing the human neocortex with scalp electrodes and magnetic probes in sufficient numbers. Nevertheless, neurobiological data and analyses show that there is a neurodynamics of meaning in behavior, which should constitute Noam Chomski's "deep structure" and, in fact, give proper meaning to his choice of words. Rather than conveying an image of decision trees, logical rules, and lexical files, the "subconceptual" "deep structure" can be visualized by images of chaotic attractors, trajectories in multidimensional state spaces, and the attendant basins of attraction - the "geometry of behavior" as Abraham & Shaw (1985) have described it. At some levels it will matter whether the words are "I want food", "Give me eats", or "Where is my dinner?" , but in his explorations into the pre-cognitive bases for linguistics in neurophysiology, it is clear that Smolensky is less concerned

with legal and lexical constituents than with the dynamics of meaning.

At another level, N. Katherine Hayles (1989) has argued persuasively that new concepts, shared in the sense of Foucault (1973) among the disciplines of literature, linguistics, and nonlinear dynamics, reflect the pervasive epistemological changes that are insistently permeating our understanding of our natural world, our culture, and ourselves. One of the most striking parallels she describes is between the iterative methodology of Feigenbaum in generating complex chaotic patterns from simple rules, and the deconstructive methodology of Derrida (1976). Each use of a word in a text modifies its meaning in a not necessarily cumulative way, leading by iteration to the same kind of indeterminacy that inheres in all feedback systems. Even the distinction between text and context becomes blurred, in the same way that the distinction between stimulus and response is unclear and uncertain, as John Dewey (1896) urged nearly a century ago. Hayles goes further and suggests that the ultimate contribution from the dynamical theory of chaos is the recognition that information is not merely conserved, in the Shannon-Weaver sense; it is created, *pari passu* in linguistic, literary, and neurodynamic brain systems. She "harmonizes" (in Smolensky's felicitous word) with our findings from experimental nonlinear neurodynamics in her emphasis on "self-similar replications" in preference to the fruitless search for "origins", and on the "shift in the ground of representation itself, which is bound to have profound implications for literature" (op. cit. p 318, and Hayles, forthcoming).

Hence the neuromacho stance is not without substance. The neuroelectric patterns that express the yearning of a rabbit for its carrot are, to be sure, pre-linguistic, but they contain and reveal the principles according to which the pre-cognitive "deep structure" (in its dynamic sense) might be formulated in ways more insightful than those of grammar and syntax.

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