Non-Declarative linguistics: Some neuropsychological perspectives

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For almost a generation now the view of language as a formal system in which explicitly represented rules manipulate abstract category symbols has dominated linguistic theory. Within the past decade, however, various non-declarative approaches such as the connectionist approaches and Skousen's analogical approach have begun to mount a serious challenge to the formal rule-symbol systems approach. While the connectionist approaches are much more widely known and applied than the analogical approach, this paper argues that Skousen's approach is both empirically and theoretically superior to those connectionist models and that the analogical approach enjoys greater biological plausibility than the connectionist systems do.[1]

1. Introduction

For almost a generation now, the predominant paradigms within linguistic theory, cognitive psychology, and artificial intelligence have promoted a powerfully persuasive image of the mind as a system of formal rules that manipulate abstract mental symbols. In our field, in particular, the defining assumptions first articulated by Chomsky (1965) of language as a formal rule-system have continued to dominate theorizing within the field despite dramatic revisions to the content proposed for such systems over the years. Within the past decade, however, new work in the modeling of cognitive behavior as connectionist[2] computer programs has begun to challenge the rule-symbol system approaches. Two important reasons for the appeal of connectionism seem to be that it matches the explicitness of traditional computational models while at the same time it presents an intuitively more plausible model of activity in the brain than the traditional approaches do.

Probably the best known application of a connectionist approach to language modeling is Rumelhart and McClelland's (1986b) parallel distributed processing (PDP) model of English verb form acquisition. That work, with its neo-behavioristic bent, has attracted enough interest to provoke vigorous responses from the champions of the rule-based systems (see Pinker & Prince 1988, Fodor & Pylyshyn 1988, Fodor & McLaughlin 1990, Pinker 1989a).

The heart of the controversy appears to be, on the one hand, that

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Rumelhart and McClelland seem to have demonstrated that connectionist systems can model the rule-like behavior of English verb morphology without actually positing or referring to explicitly represented linguistic rules and abstract category symbolics. The proponents of the rule-symbol systems, on the other hand, argue that connectionist systems – and, by extension, other such non-declarative approaches – are empirically inadequate for modeling language or other properties of the mind accurately.

The most articulate defender of rule-symbol systems to emerge to date has been Steven Pinker (Pinker & Prince 1988, Pinker 1989a). In one recent article in particular, Pinker (1991) garnered an impressive array of linguistic, experimental, and clinical evidence to bolster his claim that, for the most part, human language still is best characterized as a set of rule-symbol systems in the brain. As I have explained elsewhere (Chandler 1993), Pinker's defense of rule-symbol systems was not convincing because, unfortunately, none of the research that he cited in support of it actually requires such a system in order to explain the data. On the contrary, some of Pinker's supporting data actually appear more naturally explainable within other non-declarative models such as Skousen's (1989) analogical approach than they do within a rule-symbol system.

The connectionist approaches that Pinker objected to actually suffer from other, more general theoretical and empirical problems than those he focused on in his defense of rule-symbol systems. Ironically, it is precisely those problems that turn out to render connectionist models inadequate as models of cognition in general and of language in particular. After reviewing those general inadequacies briefly, I shall explain below how other non-declarative approaches, such as Skousen's analogical approach, overcome these inadequacies while preserving the strengths of the connectionist approaches. The result is that certain non-declarative approaches such as Skousen's provide both an empirically superior and a biologically more plausible alternative to rule-symbol systems and to connectionism.

2. *The Appeal of Connectionism*

One of the chief sources of connectionism's appeal over that of rule-symbol systems has been that the newer framework provides ways to represent and use information that appear much more plausible biologically to many researchers than the traditional rule-statement approaches do. The rule-symbol system approaches to modeling language and the mind gained a powerful influence over the cognitive sciences

throughout the 1960s and 1970s, due largely to the triple impact of dramatic post-war developments in cognitive psychology, theoretical linguistics, and artificial intelligence. Although such computer inspired models really never were very plausible biologically (see, for example, John von Neumann's 1958 disclaimer), the metaphor proved very powerful, nevertheless, and soon came to be taken as reality by many people (see, for instance, Fodor 1983, Miller & Johnson-Laird 1976, Johnson-Laird 1988, Pylyshyn 1984). It survives today mostly in the form of the rule-symbol system models such as those advocated by formal linguists and defended in Pinker (1991). The most basic problem with those models was summarized in Edelman (1987): the biological facts of neural development and organization do not make it feasible that the brain consists of microsystems that rely on complex temporal sequences of rules or that interact deterministically on data filed away in separate memory stores. What is more, the computer-like systems implied by the rule-symbol systems would, if implemented in real neurons, be too slow (Posner 1978), too rigid (Clark 1989), and too brittle (Norman 1986) to account for real cognitive processes.

In contrast to the traditional computational models, connectionist systems both store and process information as patterns of varying strength interactions among large arrays of simple processing units. Because the information is distributed over large networks of simple units and processed in parallel, gaps or irregularities in information from individual units have relatively little impact on the overall operation of the network. Indeed, when confronted with unanticipated input, connectionist systems try to make sense of those new experiences by assimilating them into whatever structures are currently represented in the system, an effort that looks much more like the behavior people exhibit than does the crashing or returning of canned responses typical of the standard information processing models (Rumelhart & McClelland 1986a). Moreover, since connectionist systems process large amounts of information in parallel, they can, in principle, model the real-time operations of cognitive processes much more realistically than serial computer programs do (Feldman & Ballard 1988, Smolensky 1988).

The input and output representations that connectionist systems accept and return look much more natural to proponents than do the typical input and output of rule-symbol systems. Because connectionist approaches interpret new inputs by comparing their perceptual features (and those of their contexts as well) in parallel with the system's schema, or summed experience over many examples of a category, the outputs will show the prototype effects for cognitive categories described by Rosch (1975) and characteristic of human performance on all categorization tasks (see Lakoff 1987).

Thus, the schematic representations of connectionist models provide naturally – that is without special additional mechanisms – emergent 'prototypes' for concepts, average standard representations from which a person can access typical characteristics on request and against which a person can judge the typicality of exemplars upon requests. Such prototypes emerge in connectionist systems because the systems average feature occurrences over large numbers of inputs to arrive at schematic network representations that are preserved as central tendencies in connection strengths among the units making up the network. However, those cognitive prototypes are not static. Their prototype effects vary according to different contexts much as people's actually do; a person's prototype for chair, for example, changes when one asks about a typical chair in a kitchen compared to a typical chair in a living room (Barsalou 1987, Clark 1989). Connectionist systems also model the interactions among co-occurring features during complex pattern recognition tasks much more naturally than do traditional information processing programs based on rules (Clark 1989, Smolensky 1988). Finally, connectionist models capture the naturally fuzzy boundaries that are characteristic of mental categories. Sometimes those boundaries are broader, fuzzier, such as the boundaries among word meanings, and other times they are much narrower, sharper, as in the categorical perception effects shown toward some speech sounds.

3. *Problems with Connectionism*

Despite the impressive successes of connectionists, and they are impressive, connectionism also shows serious theoretical and empirical flaws. Among the more important theoretical issues identified by critics is that the systems mimic the phenomena that they do through ad hoc, handcrafted network structures which, although more brain-like than conventional programs, still are not neuropsychologically well motivated (Grossberg 1987, Reeke & Edelman 1988, Pinker & Prince 1988). A second problem is that because connectionist networks store accumulated experiences as central tendencies within a common network, novel input to an existing memory representation often results in 'catastrophic interference' with the existing representations. That is, significantly different input may alter a well-established memory representation radically and irretrievably – unlike the case with real brains.

Critics of connectionist systems have also pointed out that the learning mechanism of choice in connectionist demonstrations, 'back propagation', is not biological plausible (Reeke & Edelman 1988, Crick 1989, Grossberg 1987, Smolensky 1988). Not only are there no known

synaptic mechanisms corresponding to those implied by back propagation, but the process requires feedback from an external teacher after each exemplar, and the results of that feedback must trickle backwards through the networks adjusting the strengths of the connections at each level according to the feedback. An important consequence of the learning mechanism is that the learning curves exhibited by such systems as Rumelhart and McClelland's appear to be more an artifact of how the training data were presented to the system than an inherent consequence of the learning model itself (Pinker & Prince 1988).

Empirically, the current generation of connectionist models fails to reproduce real human behavior in at least three important ways. First, as described by Skousen (1989), connectionist systems are not genuinely probabilistic although real people are. Given the same set of input variables, the connectionist systems always return the same response. Real people do not. Real people sometimes return one response and sometimes another, probabilistic responses that apparently depend, at least in part, on stimulus sampling effects and in part on the relative frequencies of those alternatives as alternative outcomes for the same input in an individual's personal experience (Estes & Burke 1967). A second empirical flaw in connectionism is that its system of schematic representations cannot model accurately the effects of memory for specific exemplars in recognition and categorization experiments (Medin & Schaffer 1978, Smith 1990, Hintzman 1986, 1988, Hintzman & Ludlam 1980). For example, even single exposures to a single example can affect a person's subsequent behavior on a categorization study, and similarity between a test item and an exemplar shows larger priming effects than similarity to an abstracted prototype does (Smith 1990). Finally, in reviewing the data on schema-based models of cognition, Alba and Hasher (1983) had to conclude that schema models alone could not represent people's memories for experiences richly enough to account for the results used to motivate schema models of memory in the first place. Virtually all studies of schema effects on learning and memory show residual effects for memory of specific details about specific exemplars that cannot be accounted for by positing schematic representations alone.

The source for all three empirical problems is that connectionist systems form cognitive categories by capturing and operating on the central tendencies of correlations among the features evoked during a system's training history with input exemplars. That is, they do not record individual memories for individual experiences with exemplars.[3] Instead, they summarize the co-occurrences of features schematically into prototypical category representations. Consequently, unlike real people, connectionist systems do not record individual memories for individual experiences and so cannot 'recall' or 'recognize' the recurrence of individual exemplars of experience (Smith 1990, Chandler 1994).

4. *The Analogical Alternative*

Despite the theoretical and empirical problems with their models, the proponents of connectionism have demonstrated at least one important principle for the cognitive sciences that the opponents of non-declarative systems do not yet seem to appreciate fully. They have shown that rule-like regularities can emerge from the massed interaction of relatively simple processes operating on homogeneous networks of information even though those networks contain and refer to no explicit representations of those rules. The problem, then, becomes how to preserve the strengths of the connectionist framework while overcoming the serious deficiencies just reviewed. In his analogical approach to describing language, Skousen (1989) offers a non-declarative alternative to both rule-governed approaches and connectionist approaches that appears to do just this.

Working independently of the connectionist framework, Skousen (1989, 1992) has developed an analogical approach to modeling language behavior which shares many characteristics with the connectionist approaches while also differing from them in several crucial respects. He has been particularly interested in describing a single framework which could account uniformly for regular (rule-governed-like) linguistic behavior, irregular (or exceptional) linguistic behavior, and the kinds of variations in usage observed in real linguistic behavior (as contrasted with the hypothetical, idealized speaker/hearer postulated of competence grammars). Basically Skousen has developed a set of mathematical procedures (and a computer implementation) for modeling and predicting linguistic usage analogically. According to his model, a speaker wanting to choose a linguistic form (for production or comprehension) compares the relevant variables of the current context (both linguistic and non-linguistic) with all possible combinations of those variables in his or her past experiences and then opts for one of the alternative forms recorded for those previous contexts. Skousen has applied his approach to several very different kinds of variable linguistic behavior and has shown how it predicts the behavior actually observed much more accurately and simply than rule-based models do.

Like connectionist models, Skousen's analogical approach accounts for seemingly rule-governed linguistic behavior without recourse to explicitly represented rules. Thus, both approaches represent non-declarative approaches. The prototype effects that give rise to rule-like regularities emerge in connectionist systems because those systems average feature occurrences over large numbers of inputs to arrive at schematic network representations preserved as central tendencies of correlations among those features. In Skousen's analogical model, on the

other hand, and in the exemplar-based models of cognition described below, the correlations among features that create the prototype effects emerge 'on the fly' (a la Barsalou 1987) during the comparison in parallel of input features to the features of accumulated tokens of experience stored in long term memory, not just to (proto)types.

Thus, Skousen's analogical model can account for the prototype effects that motivate connectionist models over rule-symbol based models. It also extends uniformly to behaviors that neither connectionist systems nor rule-schema systems alone can accommodate without exceptional mechanisms or procedures. For example, real performance with even so simple a 'rule' as the one said to govern the choice of the English indefinite article form *a* or *an* shows 'leakage', that is, occasional errors across category boundaries. Competence grammarians, with their formal rule-symbol systems, either discount such leakage as a performance problem and therefore outside the realm of their theories, or they treat it as a special case for which they invoke special considerations. Connectionist models cannot account for such 'leakage' at all because they always return the same output (form) for the same input (context). The analogical approach not only accounts uniformly for such leakage, but it also explains the preferred direction actually observed for real speakers (*a* most often displaces *an* while the converse almost never occurs), and it correctly predicts behavior in ambiguous contexts and in new contexts not defined (or anticipated) by the formal rules.

5. *Exemplars and Cognitive Categorization*

A potential hurdle to Skousen's analogical approach to language is that it implies some sort of neurological basis for encoding in memory and then later accessing and comparing as required global representations for discrete episodes of experience. At first glance his interpretation strikes many theorists as implausible because of our tradition of looking for processes of abstraction and generalization in order to 'explain' cognitive behavior. However, good experimental evidence actually exists which substantiates the cognitive processes implied by Skousen's analogical approach, and the research generating that evidence represents an independent challenge to the biological and psychological plausibility of both formal linguistic models and connectionist models.

For over a decade now, the issue of whether people abstract prototype-like mental schemas summarizing their experiences with exemplars has been the focus of much debate and research within the literature of concept formation and category learning. In 1978 Medin and Schaffer published experimental results indicating that people categorize and interpret new experiences by comparing them to accumulated memories for individual exemplars rather than by reference to some abstracted prototype or schema. Today, a sizable body of experimental research on category formation has established that people do encode episodic memories for very specific chunks of experience and that they use those exemplar memories of past experiences as the basis for categorizing and interpreting new experiences (cf. Medin & Schaffer 1978, Barsalou 1987, Hintzman 1986, 1988, Hintzman & Ludlam 1980, Nosofsky 1988).

Not only do exemplar-based models of categorization exhibit the variable prototype effects and graded internal-structure effects characteristic of all cognitive categorizations, including linguistic categories (see, for example, Ross 1973, Sag 1973, Kuno 1987, Pinker 1989b, Hopper & Thompson 1984, Lakoff 1987 for discussions of graded linguistic categories), but, as noted earlier, they also turn out to be empirically superior to schema models in accounting for other observed effects. These effects (as summarized in Neisser 1987 and Smith 1990) include the ability to create on demand new, ad hoc cognitive categories that are most likely based on episodic memories for experiences with exemplars (Barsalou 1985, 1987); preferences for comparisons of new input to previously experienced exemplars, even to single exposures of an exemplar, over comparisons to presumed schematic representations of prototypes; and, finally, stronger priming effects for similarity to an exemplar than for similarity to a prototype. Even single past experiences can affect new category judgments as much as established schemas seem to.

As a result of studies such as those summarized in Smith (1990), it is clear today that any adequate model of learning and memory will have to include mechanisms for encoding and recalling episodic memories for experiences with individual exemplars, something that standard connectionist models cannot do. That is, the model needs to include some sort of mechanism for using the experiences stored as episodic memories to categorize and interpret new experiences. Computer simulations such as Hintzman's MINERVA (1986, 1988) have modeled explicitly how such episodic memories could give rise to the behavior, including the prototype effects, recorded in the experimental studies of category formation.

6. A Neurological Mechanism

While Skousen's analogical approach to language and the experimental literature on exemplar-based concept learning both demonstrate systematic cognitive behavior based on reference to accumulated memories for individual episodes of experience, neither

body of work suggests a neurological mechanism for encoding, storing, or accessing and processing such a behavioral data base. Fortunately, recent work by Burton (1990), and corroborating work (my interpretation) by Damasio (1989) and Squire (1992), among others, suggests the components of a neurological model capable of explaining the learning, encoding, and accessing of concepts within an exemplar-based model of cognition (Chandler 1994 provides a more extensive description of the neurological model).

In an extensive survey and new synthesis of research on possible neurological bases for cognition, Burton (1990) proposed a psychonomic model for learning and accessing what I interpret to be just the kinds of information implied in Skousen's analogical approach to language and in the experimental literature on exemplar-based cognition. Burton focused on the earliest stages of learning, on how a child's sensory system could begin to make sense of meaningless, seemingly chaotic, sequences of sensorimotor impressions, but he also extended his model to aspects of early language acquisition. Burton's model does not posit any specific innate knowledge of language or other conceptual structures but instead grounds all learning directly on the neurological representation of individual sensory experiences.

The overall model – tied explicitly to real-time operations of specific anatomical units in the brain – can be visualized as accumulating sequences of discrete perceptual snapshots, much like the frames of a movie film, but instead of being strung out in linear order, they are layered temporally one on top of another. Each 'frame' is an episode, a cross section of all the sensorimotor and affective information active throughout the cerebral cortex at the time of the cognitive snapshot. Some minimal change in the input information from within the perceptual field contrasted against the relatively stable background input triggers a global proceed-to-store signal. Accumulating such snapshots gives a learner a data base to begin building a perceptual representation of an object as a temporal sequence of feature transformations. On subsequent occasions, encountering a sufficiently similar set of features and feature transformations evokes in parallel the memories for previous experiences with an object. Those parallel representations of previous experience provide an ad hoc prototype 'on the fly' (a la Barsalou 1987) and allow the learner to further distinguish the object against a probably now somewhat different background. As a learner gains more experience with an object or similar objects, he or she will come to expect the sensory transformations to follow routine sequences. Any novelty in that sensory input will tend to attract his or her attention to the features corresponding to the novelty. In this way, a learner develops an increasingly detailed inventory of perceptual experiences including the contexts that have gone with them.

In Burton's account such perceptual learning occurs automatically and largely unconsciously without benefit or need of an external tutor, but it can lead only to perceptual learning, that is to the conjoining of shared perceptual attributes. Indeed, the process dissociates seemingly random co-occurrences of disjoint perceptual sequences such as the visual sequences corresponding to an object and the separate auditory sequences of on-going speech. A linguistic symbol, on the other hand, is an arbitrary association of just two such disjoint perceptual objects, a referent and a phonological form. Thus, in Burton's interpretation, the association of two such disjoint perceptual objects requires the intervention, at least initially, of some external agent who contrives the temporal coincidence of the objects and who works to draw the learner's attention to both objects simultaneously. Consequently, the earliest steps of such language acquisition are laborious, tedious, and highly context bound, but once the child has learned the basic notion of 'linguistic symbol', the process begins to snowball and becomes a major force in the child's conceptual development. Nonetheless, it remains essentially a process of forming arbitrary associations among pairs of inherently disjoint percepts.

7. *Some Conclusions and Implications*

The neuropsychological framework sketched in this paper for thinking about language and cognition differs radically from most other accounts of how language may be represented in the brain and used. Nevertheless, the three lines of independent research discussed here, Skousen's analogical approach to language, the work on exemplar-based cognition, and the proposed psychonomic model of episodic learning, provide solid theoretical and experimental support converging on a new picture of how people acquire, store, and access a basis for language use which does not rely on explicit representations of linguistic rules or on schematic representations of linguistic forms. Within this new framework, functional linguistic forms – that is, individual pairings of form (pronunciations, prosodies, words, and syntactic patterns) – and communicative functions emerge as accumulations of memory representations for individual exemplars of usage rather than as abstractions from experience.

Although language acquisition researchers hardly ever discuss the underlying mechanism involved, virtually all models of language acquisition imply some sort of exemplar-based learning mechanism as their entry point to rule-learning or schema abstraction. Perhaps most explicit is Braine's (1976) proposed sequence of phrase structure rule

development. He described evidence of children first accumulating exemplars of phrases (specific word combinations, or "position associative patterns"). After accumulating some critical number of examples, a child then abstracts a general phrase structure rule (a "positional productive pattern") for the word classes involved. Braine argued that when children begin to use a pattern productively and are no longer constrained to the fixed phrases that they had actually heard modeled, that productive usage itself was *prima facie* evidence that the child had abstracted a rule schema. However, both Skousen's computer implementation of his analogical approach and Hintzman's computational model of exemplar-based cognition interpret and produce novel forms on analogy with exemplars stored in memory even though their systems never explicitly develop rules or other abstract symbolic representations of the linguistic structure.

The category and rule abstraction process described by Maratsos (1982, 1988) also includes explicitly the storing and comparing of individual exemplars of language use. Maratsos argued that children form word classes and other syntactic categories by noticing the recurrence of language forms in different linguistic contexts. Those contexts themselves eventually form the basis for inducing structural and functional definitions of mental syntactic categories such as noun, adjective, verb, etc. Finally, even Pinker's 'bootstrapping' process (1984, 1989a) for recognizing initial examples of allegedly innate syntactic categories and predicate structure constraints assumes some sort of global representation for utterances and their meanings. The subsequent bootstrapping that categorizes the input depends crucially on the learner being able to evoke appropriate exemplars from memory and to compare them with the new input.

The non-declarative approaches advocated in this paper imply that any perceivable distinction between two episodes of experience may – potentially – serve as a feature for comparing and distinguishing the objects and events of those episodes. Of course all being available does not make all equally likely. Differences in salience, context, and experience make some potential attributes more noticeable sometimes than others. Thus, we see that the people of the world collectively use a large number of perceptually distinct features to make up the phones of their languages, yet some features are very common across languages while others are, for whatever reasons, very rare. So it goes for all acts of perception. In accumulating memories for exemplars, the brain and its sensory channels can only sample the information available to it. Therefore, not all perceivable aspects of every experience will be encoded in memory (Estes & Burke 1967), but as Burton explains, in a given episode, those features perceptually useful for distinguishing objects from their background are most likely to be compared with earlier memories and stored as a new episode.

The sociolinguistic research (see Labov 1970, Skousen 1989, Tarone 1988) confirms that virtually any distinguishable characteristic in a sociolinguistic context may come either to motivate or to mitigate subsequent use of a particular linguistic form in a slightly different context. Thus, it appears correct to say that there is no a priori set of features which a theorist can predict ahead of time that will be the relevant features in a cognitive system. Instead, the relevant features emerge from an individual's perceptual experience as that person accumulates more and more memories for episodes of experience. Both the consistently noticed differences and the consistently noticed similarities become our bases for perceptual categorizations.

The non-declarative mechanisms modeled by Skousen's analogical approach and described in Chandler's exemplar-based framework lead language learners to behave as if they had abstracted functional linguistic generalizations – that is, as if they had associated words and syntactic structures with particular communicative functions – including sociolinguistic functions. However, what the learners are actually doing is accumulating ever larger collections of contextualized communicative experiences which become the users' data base for formulating or comprehending new utterances in new contexts. Thus, the major significance of Skousen's work and that of other non-declarative linguists is to demonstrate empirically that a biologically plausible system, one well-motivated by a considerable body of experimental data, can account for systematic linguistic behavior without reference to explicitly represented linguistic rules or abstract category symbols. In doing so, such work contributes a radically new perspective to the fundamental debate over what the very nature of the human mind is and how it arises in the brain.

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2 I use 'connectionism' here as a cover term for a variety of similar approaches such as parallel distributed processing (Rumelhart & McClelland 1986), neural networks (Grossberg 1987), and neural Darwinism (Edelman 1987).

3 Kruschke (1992) has tested a hybrid connectionist-exemplar-based model of category learning. While his model may overcome the memory-for-exemplars defect inherent in pure connectionist models, it does not address the theoretical deficiencies described. As Barsalou (1990) has demonstrated, it is possible to build hybrid models that make the two categories of models empirically indistinguishable. However, such models also obscure the relative strengths and contributions of the two distinct approaches to understanding cognition and learning.

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