

BOOKS: LANGUAGE

Why Do Kids Say Goed and Brang?

James L. McClelland and
Mark S. Seidenberg

Sagan had an unconventional ability to fathom the panorama of unanticipated, low-probability results or outcomes that nevertheless may occur and might even have huge consequences. Such views often justify unpopular caution (about the danger of extraterrestrial contamination of Earth, for example), and they endorse sheer exploration as a valid alternative scientific strategy to traditional goal-directed hypothesis testing.

In Hollywood and professional sports, celebrities suffer the crush of fans with their friends, and their agents shield them from impossible pressures or threats. Sagan was equally famous, yet had no comparably famous scientific peers with whom to commiserate. Despite the loyal efforts of his wives and of his long-time secretary Shirley Arden, Sagan's personal and academic support structure was unfamiliar with handling celebrity. Sagan's colleagues, however, often scorned his self-protective measures and rarely imagined how they might cope in his shoes. Some felt snubbed when his priorities turned toward averting nuclear war. History will decide whether Sagan was only a bit-player or was more influential, but should we complain about having one of our own at that table?

Should Sagan really have chosen, in the late 1970s, to continue editing *Icarus* and researching aeolian processes on Mars, rather than to embark on *Cosmos*? Do Sagan's critics really want no books like the Pulitzer Prize-winning *Dragons of Eden*? If Sagan had not been available to journalists for comments on someone else's spacecraft results, would there have been any coverage at all? Scientists became so jealous that Sagan was famously barred from membership in the National Academy of Sciences and his nomination for a posthumous award from his narrowest circle of professional colleagues even met obstacles. Is that a reflection on Sagan or on his colleagues?

We need dedicated specialty researchers, but we also need broader multidisciplinary synthesizers. Carl Sagan gave us even more than that: He was, for all his failures to meet the ideals of others, a renaissance man during an age when that was—and still is—virtually impossible (and is sometimes even held in disrepute). We should be grateful for the treasured moments so many of us shared with Carl. I occasionally had my own one-on-one hours with him, but I also joined countless millions who watched him on Johnny Carson and *Cosmos* or read his well-crafted writings. An enormous fraction of my younger colleagues credit Sagan with turning them to science at a time when science was in cultural retreat. Both these biographies offer informative perspectives on how and why he was able to do that.

As Steven Pinker notes in his new book *Words and Rules*, kids say the darnedest things. In the late 1950s, language researchers noticed that kids occasionally say odd things like “Daddy goed to work” and “I taked the last cookie.” These past-tense forms were intriguing because children seemed to be generating them without having heard them before. And indeed, when children were tested with nonce verbs such as “glick” and “mott” they often generated novel past-tense forms like “glicked” and “motted.” These forms suggested that the children had discovered a simple rule for forming the past tense: add a variant of “-ed” to the base form of the verb. Such actions fit Noam Chomsky's argument that syntactic rules are the basis of our grammatical ability. Thus the formation of novel past-tense forms came to be taken as the quintessential demonstration that language is produced through the use of a system of rules.

But if language involves the application of rules, why are there so many exceptions? Why is the past tense of take “took” instead of “taked”? Why do we use “stood,” not “standed”? “sang,” not “singed”? and “went,” not “goed”? Within the rule-based framework, explanations of such apparent exceptions follow two approaches: One tries to construct a more complex set of rules (to cover all the cases). The other introduces a second mechanism, a mental lexicon, to handle cases where the usual rules do not apply.

Perhaps, however, the brain stores language in a way that systems of rules and lists of words can only approximate. The rules of language, such as the past tense, need not be explicitly represented. They could instead stem from the operation of more fundamental underlying processes. In the mid-1980s, a group of psychologists, neuroscientists, and computer scientists be-

gan to explore the possibility that lawful performance might reflect the operation of a mechanism that never constructed or consulted a rule per se. For example, in the production of past-tense forms of verbs, the mechanism might simply adjust the connections among the neurons involved in forming past tenses when the network encounters the past-tense form of a word.

David Rumelhart and one of us (McClelland) developed this idea using a computer simulation of a simple neural network (1). The model had two sets of neuron-like units, one for representing the base form of a verb, and one for representing its past tense. The model was trained using repeated presentations of present and past-tense pairs. After each presentation, the connections from the units representing the features of the present tense to the units representing the features of the past tense were adjusted by a small amount to allow the active input units to excite the appropriate output units. The

model captured the correct use of both regular and exceptional forms, and it exhibited the capacity to generalize. Thus, within a single network, it accounted for many essential aspects of the past-tense phenomena without a rule or a lexicon.

At this point, Steven Pinker entered the debate. Now well known through his popular science writing, Pinker emerged as a prominent psycholinguist on Chomsky's home ground at the Massachusetts Institute of Technology. In an influential article (2), Pinker and Alan Prince drew on their broad knowledge of language to develop a blistering critique of the neural network model. After correctly noting several shortcomings of the specific model used by Rumelhart and McClelland, they went on to claim that no neural network could ever adequately capture the generality and absoluteness of the English past-tense system.

In a later paper (3), however, Pinker acknowledged that the neural network model did have some positive properties. Unlike a standard lexical lookup mechanism, it captured another type of generalization based on patterns found among the exceptions. Using the pattern found in pairs like “sing-sang” and “ring-rang,” children sometimes say “brang” for the past tense of “bring.” Writing rules to capture the fact that some verbs form their past tense by changing “i” to “a” won't do, said Pinker, because such rules are not fully generative. The pattern only applies to some words with the short vowel “i,” and the ones it does apply to share a “family resemblance” structure of the kind that was well captured by the neu-

Words and Rules The Ingredients of Language by Steven Pinker

Basic Books, New York,
1999. 362 pp. \$26,
C\$39.50. ISBN 0-465-
07269-0.

James L. McClelland is at the Center for the Neural Basis of Cognition, and the Department of Psychology, Carnegie Mellon University, 115 Mellon Institute, Pittsburgh, PA 15213, USA. E-mail: jlm@cnbc.cmu.edu. Mark S. Seidenberg is in the Neuroscience Program, and the Department of Psychology, University of Southern California, 3614 Watt Way, Los Angeles, CA 90089-2520, USA. E-mail: marks@gizmo.usc.edu

ral net. (They often end in “-ing,” but may end in “-im” as in “swim,” “-in” as in “begin,” or “-ink” as in “drink.”) So, Pinker suggested, we use a rule to form regular past tenses, but a mechanism very much like the Rumelhart-McClelland network to formulate irregular past tenses.

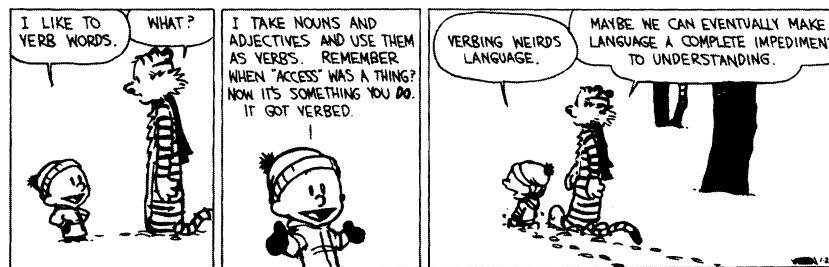
Since Pinker proposed these ideas in 1991, he has pursued them in a wide-ranging series of studies. He and his collaborators have analyzed children's spontaneous speech to discover whether the use of the regular past tense develops abruptly or gradually. They have studied adults' acceptance of such sentences as “the slugger flied out to center field” versus “the slugger flew out to center field.” They have explored other putative rule-based systems such as the German plural. And they have examined people with brain damage to see if they could find one group lacking the ability to apply the past-tense rule and another group unable to correctly produce exceptions.

In *Words and Rules*, Pinker offers a very approachable summary of his ideas and the results of his research. Reviewing the history we sketch above, he notes the depth of the challenge that the neural network view poses to conventional rule-based approaches, and he provides many amusing examples to punctuate his arguments. Pinker considers two single-mechanism approaches—using only rules and using only a neural net—and presents his reasons for believing that neither approach will do by itself and that combining positive features from both is the only plausible approach. He introduces simple ideas clearly and complex ideas gradually, so readers without a background in the field will not be left behind. Along the way, he attempts to explain many puzzling and amusing quirks of language, such as the fact that although we tend to describe someone who eats rats as a “rat eater” rather than a “rats eater,” we accept both “mice eater” and “systems analyst.” Similarly, Pinker tries to explain why we say “ladies in waiting” and not “lady in waitings,” but “major generals” and not “majors general.” Overall, the book tells quite an engaging story, one that anyone who has puzzled over the quirks and foibles of language is quite likely to enjoy.

While everyone may agree that Pinker's story is a pleasure to read, it is important to realize that *Words and Rules* hardly reflects a consensus view. Instead, it represents one of several positions, each championed by a band of ardent adherents. Pinker makes no

attempt to hide this; he states his beliefs and preferences, presents the case for his point of view, and discusses what he sees as the shortcomings of the alternatives, particularly the neural-network approach.

Will this book settle the debate? We do not think so. In our view, it suffers from too many serious problems. Pinker sees the evidence from the empirical studies through rule-tinted glasses. For example, he repeatedly refers to abrupt transitions in children's use of the regular past tense, which are consistent with the sudden discovery of a rule. But the relevant data (4) show much more gradual transitions, as expected in the neural network framework. A subtler form of misperception pervades Pinker's discussion of studies that rely on judgments of acceptability of possible past-tense and plural forms. Many “regular” past-tense forms receive intermediate values on a graded acceptability scale.



“Calvin and Hobbes” by Bill Watterson.

Such graded judgments appear more consistent with the effects of continuous-valued connection strengths (found in a neural net) than with symbolic rules—which are, as Pinker says, “operations that apply fully to any instance of a category.”

Nor does Pinker present an explicit model of the processes by which past tenses are generated. There are gaps and inconsistencies in his explanation of how such items are formed. For example, Pinker fails to adequately describe how knowledge of a cluster of similar past-tense forms gives rise to productive generalization (such as the production of “brang” for the past tense of “bring”). He appeals to broad characteristics of the Rumelhart-McClelland model to address such issues, but also to a traditional notion of lexical entries. His presentation does not demonstrate how these concepts can be reconciled or how his proposed system can capture detailed aspects of the phenomena.

Pinker also mistakenly assimilates all neural network models into an older theoretical tradition called associationism, which interprets intelligence as the linkage of “ideas that have been experienced in close succession or that resemble one an-

other.” After casting the crucial theoretical issue as a contest between rule-based and associationist approaches, he argues for a dual system that uses both, without fully recognizing how neural network models erase the distinction between them. Pinker dismisses a host of newer neural network models as adding very little beyond the capabilities of the original Rumelhart-McClelland net, consistently underrepresenting their capabilities. Thus, despite forthrightly acknowledging how revolutionary neural network models are, he stops short of conveying their full potential as the basis for the productive use of language.

Pinker's analysis of the formation of the English past tense is reminiscent of the astronomer Tycho Brahe's attempt to come to terms with Copernican theory. Tycho formulated a compromise that captured some of the appeal of the Copernican approach, while maintaining the key Ptolemaic principle of geocentrism. Correspondingly, Pinker has seen some of the appeal of the neural network approach, and he has found ways to incorporate elements of it in a compromise position that maintains the key principle that language knowledge consists (at least in part) of rules.

He relies on the properties of neural networks to address problems with the traditional rules-plus-words point of view. His resistance to the core tenets of the neural network framework, however, leaves him—like Tycho—with a compromise that really deals only partially with the challenge posed by the emerging system.

Thus it may be fitting that *Words and Rules* appears at the end of the old millennium. Written amidst an ongoing research debate, it captures a transitional mode of thought that may be typical of a scientific revolution in progress. Pinker supplies an engaging treatment of an attempt to find a middle ground between two incommensurate theoretical frameworks, and he provides numerous entries to the stream of ongoing research in which the full potential of the newer, neural network approach will eventually become apparent.

References

1. D. E. Rumelhart and J. L. McClelland, in *Parallel Distributed Processing: Explorations in the Microstructure of Cognition*, vol. 2 of *Psychological and Biological Models*, J. L. McClelland, D. E. Rumelhart, the PDP Research Group (MIT Press, Cambridge, MA, 1986), pp. 216–270.
2. S. Pinker and A. Prince, *Cognition* **28**, 73 (1988).
3. S. Pinker, *Science* **253**, 530 (1991).
4. G. F. Marcus et al., *Monogr. Soc. Res. Child Dev.* **57**, 1 (1992).