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Author

Jones, Nancy

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Words and Rules: The Ingredients of Language by Steven Pinker
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Reviewed by Nancy Jones
University of California, Los Angeles

Words and Rules, the latest popular offering from the prolific MIT linguist Steven Pinker, although characteristically clever and well-written, does not offer any surprises to those familiar with his other works. Pinker first introduced the premise underlying *Words and Rules* in his 1994 *The Language Instinct*:

The way language works, then, is that each person's brain contains a lexicon of words and the concepts they stand for (a mental dictionary) and a set of rules that combine the words to convey relationships among concepts (a mental grammar. (p. 85)

Words and Rules expands upon this premise and provides some new twists on an old theme, as Pinker focuses on regular and irregular verbs as a means to show that words and rules are the "ingredients" of language.

Over the course of his argument, Pinker also attempts to rule out two competing language theories: Chomsky and Halle's (1991) generative phonology model and Rumelhart and McClelland's (1986) connectionist model. For those interested in the ins-and-outs of the past tense or an overview of the connectionist model as it applies to verbs, this book is worth a read. However, Pinker fails to convince the reader that connectionist models can immediately be dismissed—nor does he adequately demonstrate how his own "words and rules" model gives us insight to cognition.

Pinker's theory states that language consists primarily of a grammar for production of novel utterances (*rules*) and a lexicon of memorized sound combinations (*words*). Pinker asserts that the grammatical behavior of regular verbs demonstrates how we use rules to generate words while the behavior of irregular verbs illustrate the role that memory plays in word generation. Pinker gives a historical explanation for the fact that certain irregular verbs have similar forms. He states that the irregular verbs originally were generated by rules and later, through language change, became memorized forms.

Comparing this "words and rules" theory to Chomsky and Halle's generative theory and to the connectionist/neural net theory of Rumelhart and McClelland, Pinker concludes that neither Chomsky and Halle's model nor Rumelhart and McClelland's model adequately explain the behavior of regular and irregular verbs.

Chomsky and Halle's model asserts that both the regular and irregular forms

of verbs are generated by rules *in situ*. The production of the regular and irregular verbs is generated by the application of generative phonological rules. The boldest claim of Chomsky and Halle's theory is that the form of the word that is held in a speaker's "mental dictionary" is an *underlying* form which may be radically different from the form that the speaker produces (Pinker, 97). Phonological rules apply to this underlying form to produce the form that is pronounced. These phonological rules apply not only to phonemes (sounds) but also to the features of the phonemes (e.g., place or manner of articulation). For regular verbs, for example, there would be an "add -ed" rule. Irregular verbs would be tagged in memory for the vowel change rules (136).

Pinker's theory differs from Chomsky and Halle's account in its insistence that rules are *not* necessary to produce irregular forms. The forms could also simply be memorized, a strategy that may even be computationally simpler. Furthermore, claims Pinker, children, when acquiring language, are exposed to surface forms, and not "underlying" forms. Another objection Pinker raises to the Chomsky/Halle model is that the similarities among groups of irregular verb stems are not accounted for by phonological rules. Having to determine the underlying forms and the transformation rules from the surface forms places a heavy computational burden on the child. Based on Pinker's reservations, it seems reasonable to conclude that Chomsky and Halle's explanation of children's acquisition of such language skills makes a fundamental aspect their generative phonology model untenable.

Rumelhart and McClelland's "connectionist" model, on the other hand, assumes that there is *no* need for rules to generate language. Patterns of language, they claim, are produced entirely by making associations from input. This pattern associator model consists of a neural network bound at its two extremes by an input layer and an output layer. The input layer would recognize the features of the verb stem and the output layer would produce the actualized sounds. The more often certain input (such as features of the sounds in a verb stem) occurs, the stronger the connections between it and its output will be. When a signal is input, paths of strongest connectivity along the net direct progressively enhanced signals to the output layer.

Thus, before such a neural net can be used to produce the past tenses of a set of words, it must be trained on a set of words and their correct past tenses. The model is then conditioned towards the pattern for the correct form of the verbs since there are strong connections for the features of the correct form of the verbs. Pinker admits that the model performs well in some areas (correctly computing the past tense for 420 words and for three-quarters of 86 novel verbs) and that it *somewhat* behaved as children do when acquiring language in that it produced regular forms for irregulars such as *gived* (p. 108).

However, Pinker then points out what he considers to be three major flaws with the model: (1) the pattern associator can only produce verb forms and cannot be made to recognize verbs *qua* verbs, (2) the model depends too much on phonol-

ogy and therefore cannot distinguish between homonyms, and (3) the model had to be manipulated in order to replicate the behavior of children acquiring a language (pp. 110-111).

At several points throughout *Words and Rules*, Pinker does assent that the failings of both the generative phonological model and the neural net model might be attributed solely to specific details of the models (such as the number of rules or the number of nodes, respectively). More frequently, however, he attempts to show that both these models of language use have problems with their underlying assumptions: "...that memory is compressed to a minimum, in the case of Chomsky and Halle, and that [in the case of Rumelhart and McClelland] generalization works by the laws of association..." (p. 122). To expand upon this point, Pinker examines what the underlying assumptions of each of these two models imply about the frequency effects of regular and irregular verbs.

According to Pinker's own "words and rules" theory, there should be no frequency effects for regular verbs, since regular verbs are generated by the use of rules. Irregular verbs, on the other hand, are not generated by rules, but are memorized as whole lexical items. Thus, frequently used irregular verbs should be accessed from memory faster than infrequently used irregulars. To test this hypothesis as it manifests in the behavior of human subjects, Pinker cites studies by Ullman (1999) and his own study with Prasada and Snyder (1990)—both of which reveal that more frequent irregular past tense verbs are retrieved faster than low-frequency irregulars. Moreover, these studies found no significant difference in retrieval rates between high and low frequency regular verbs. These behaviors are as would be predicted by Pinker's "words and rules" model.

Pinker further claims that while the Chomsky and Halle model adequately explains the behavior of the irregular verbs, the behavior of the regular verbs presents problems for the model's assumption that the role of memory is minimal in language. That the generative phonological model successfully accounts for the behavior of irregular verbs would be expected, claims Pinker, since irregular verbs are tagged for the vowel change rules and tags are strengthened through usage (p. 136).

According to Chomsky and Halle's theory, all verbs would be generated by rules to minimize the use of memory. This seems to explain the above data on irregular verbs. Pinker, though, has problems with how the generative phonological model accounts for the behavior of regular verbs. He summarizes the results of four studies that show that some regular verbs are indeed stored in memory. In all these studies, the subjects took a few hundredths of a second longer to recognize rare regular verbs than they did to recognize common regular verbs.

Pinker sees this as evidence for the advantage of his "words and rules" theory over the generative phonology theory, since it argues for a greater role of memory and shows that in some cases, both rules and features of memory are active for a given verb. This difference, however, seems to be minimal considering that the time delay is so small and that the Chomsky and Halle theory could also account

for the data. Thus, Pinker's criticism of an underlying assumption of the Chomsky and Halle theory—the assumption that memory is compressed—is not fully convincing.

On the other hand, artificial neural networks based on Rumelhart and McClelland's connectionist model, claims Pinker, failed to behave as human beings do when using language. These neural networks had slower response times for all uncommon verbs whether regular or irregular (p. 135). To prove this, Pinker looks at studies investigating human subjects' responses to novel words in three categories: (1) those that look like regular verbs (e.g., *plip*), (2) those that look like English irregulars, (e.g., *spling*), and (3) those that violate rules of English phonology (e.g., *toasp*).

Human subjects successfully conjugated the novel verbs in the first and third categories. For the novel verbs in the second category, these subjects were more likely to form the past tense of the novel word by using an irregular verb pattern. The connectionist pattern associator, however, could not generalize the regular pattern to the verbs in category three. Pinker sees this as a vital failure of the model. He states:

A pattern associator's ineptitude with novel combinations appears to be deeply rooted in its design, not just a failing of a first-generation implementation. Many connectionists have gone back to the drawing board, but none has been able to get a pattern associator memory to generate new regular forms properly. (145)

Pinker is probably too hasty in dismissing the neural net proposal. First, it is premature to dismiss the model because the model does not perform exactly as human beings do on psycholinguistic tests. For although we know that human brain function is at least partly constituted the firing of neurons, we do not know yet exactly what the pattern of neural firing is when we produce language. It may be the case that our brains do produce and process language according to an associator pattern, but that the number of connections needed to produce language is much larger than what is contained in an artificial neural net. On average, such nets contain 0.6×10^9 synapses per mm^3 (Parent, 1996). Yet, young children often have several times this amount. Thus, the inability of the neural net model to process language in the way that human brain does may be due to the fact that the net contains fewer connections than does the brain, and not to the suggestion that concept behind the model is incorrect. Furthermore, such neural nets are trained on minimal sets of information. Perhaps human beings' associations are faster and more complete because we have more information with which to construct our conclusions.

It has been pointed out that another problem with Pinker's eagerness to dismiss the connectionist model is his lack of recognition that and his model and the connectionist model are seeking explanations at different levels of abstraction. In his model, he already assumes symbols and in fact, sees this as a shortcoming of the connectionist model, claiming that "pattern associator memories, unlike symbol crunchers, cannot exploit the basic gadget of computation called a variable"

(p. 144).

One of Pinker's goals in proposing his model is to offer an explanation of how the mind produces and parses language. If Pinker truly wants to develop a model that reflects cognition or brain function, he must at least take into account a model that uses neural-like mechanisms, even if these are rudimentary. It remains to be seen just how well artificial neural nets can model human language. For now, they do at least attempt to explain language activity without assuming symbols. Given the current state of cognitive neuroscience, it might be wiser to continue to consider how the neural net theory might inform more psycholinguistic theories such as Pinker's instead of seeing the two as incompatible.

Throughout the book, Pinker often makes a convincing case for his "words and rules" theory. However, although this theory may help explain surface linguistic behavior, it does not necessarily give us any insight to the neural underpinnings of language. In its penultimate chapter, *Words and Rules* reviews some recent neurolinguistic studies in an effort to show how their findings may relate to the subject of regular and irregular verbs. Here Pinker presents findings from fMRI and PET studies concluding that regular and irregular verbs are processed in different parts of the brain. While this is an interesting finding, it alone does not give us any information about how the brain processes language. Additionally, it is not clear exactly how this relates to or supports Pinker's "words and rules" theory.

Perhaps the greatest strength of *Words and Rules*, however, is the thoroughness of the work. In it, Pinker offers abundant examples and data from psycholinguistic studies, philosophy, historical linguistics, and popular culture. A reader interested in a thorough examination of regular and irregular past tense—as well as in how plurals are used in compounds and in how people deal with novel verbs—will appreciate the completeness of its approach.

Moreover, as a popular author, Pinker writes well and excels at making interesting observations. Yet, the observations in *Words and Rules* do not reveal as much about the cognitive aspects of language as Pinker might lead his readers to believe. For while the "words and rules" model that forms the basis of the book may be a useful model for explaining language behavior, it is not clear that it adequately accounts for the underlying neural mechanisms underlying language and cognition.

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