

Peters P S & Ritchie R W. On the generative power of transformational grammars.  
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[University of Texas, Austin, TX and University of Washington, Seattle, WA]

The shift of focus in linguistic theory to transformational grammars was not immediately accompanied by application of mathematical techniques to transformations. Our purpose was to foster such studies by providing general definitions that model grammatical transformations as mappings on trees and by investigating questions such as falsifiability of transformational theory by various sources of empirical evidence, and the decidability of languages generated by transformational grammars. We showed that every recursively enumerable set of strings is a transformational language, that the power of transformational grammars to generate undecidable languages results from their ability to cycle their rules, and that the amount of cycling permitted by a grammar and the complexity of the recursive set it generates are related. [The *SCI*® and the *SSCI*® indicate that this paper has been cited in over 55 publications. It is the highest ranking paper for this journal.]

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We met in 1965 at a summer workshop at the Massachusetts Institute of Technology (MIT), organized by Noam Chomsky. His book,<sup>1</sup> presenting a synthesis of several years' work on strengthening the theory of transformational grammar to overcome weaknesses in predicting syntactic properties of human languages, had just been published. The workshop was devoted to mathematical investigation of the strengthened theory. Our backgrounds and interests led us to collaborate to determine whether the recently added restrictive conditions had strengthened transformational theory enough to overcome previously noted predictive weaknesses. Ritchie's doctoral dissertation in mathematics classified problems by their computational complexity; Peters was an MIT graduate student in

linguistics with an undergraduate degree in mathematics.

Our goal of proving that the generative power of the new theory was circumscribed (e.g., that only decidable languages—those with an algorithm to decide whether a sentence is grammatical—are generated) required us to define rigorously the range of grammars permitted. This in turn required precise formulation of features of the theory that it had not previously been necessary to specify, because empirical application of the theory could proceed in the presence of some indeterminacy. We confirmed with Chomsky the faithfulness of these formal definitions to his intent.

We were able to prove that the computational complexity of the language generated by a transformational grammar is approximated by the number of times transformations are applied as each sentence is derived. Since this number can be unbounded, transformational grammars can generate (even with the added restrictions) any language that an arbitrary computer program can construct (i.e., any recursively enumerable language). This result was very surprising because the condition requiring deletions to be recoverable had been claimed to guarantee decidability.<sup>2</sup> We showed that some *ad hoc* conditions would constrain this expressive power and posed the challenge of finding linguistically natural conditions with similar effect.

The paper was the first in what turned out to be a series, although our geographic separation led to publication delays and resulted in some papers that were written later appearing in print earlier. The successor papers showed that certain hypothetical constraints would (and certain others would not) increase the predictive power of transformational theory. In particular, we showed that constraints on the base component were predictively useless, and we discovered that the Universal Base Hypothesis is neither empirically confirmable nor falsifiable (i.e., both it and its negation are consistent with the theory of transformational grammar in combination with any possible empirical observations).

For much of the next decade, linguists sought empirically motivated ways of constraining transformations to prevent them from generating structures not possible in human languages. In part under the impetus of our theorems, the balance of effort shifted away from application of transformational theory to larger fragments of language and toward finding genuinely predictive constraints. Our paper was often cited as motivation for the urgency of these efforts. [See reference 3 for a more recent book in this field.]

1. Chomsky N. *Aspects of the theory of syntax*. Cambridge, MA: MIT Press, 1965. 251 p. (Cited 2,795 times.)
2. Katz J & Postal P. *An integrated theory of linguistic descriptions*. Cambridge, MA: MIT Press, 1964. 178 p. (Cited 390 times.)
3. Newmeyer F. *Linguistic theory in America*. New York: Academic Press, 1980. 290 p.