Inferring a grammar from responses: Discussion of Gough and Segal's comment¹

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Abstract

In the light of Gough and Segal's comments, a more detailed discussion is presented of various lines of argument which lead to the conclusion that the regularities learned in a previous experiment are not adequately represented by rules of the kinds permitted in finite state grammars. Some evidence against a proposed transform grammar is also reported.

Discussion

In their very interesting comment on my (1965) experiment, Gough & Segal (1965) present some additional reasons in support of my conclusion that a finite state grammar (FSG) was not a valid representation of the relationships learned in this experiment. They also criticize the form of my own argument for this conclusion, and in doing so they raise the question of the kinds of inferences that can be made from responses to grammatical representations of what is learned in a memory experiment of this sort. This question is by no means simple, and needs to be considered.

In the experiment Ss listened to 24 three-word strings, each repeated several times. Twelve of the strings began with a word, a, and ended with another word, b; the other 12 strings began with p and ended with q. Twelve words ($x_1, x_2, \dots, x_{12}$) appeared in the frame a...b, and a partially overlapping set of 12 ($x_1, \dots, x_6, x_{13}, \dots, x_{18}$) appeared in the frame p...q. Retention tests showed that Ss generally learned the positions of all items, and also the a—b and p—q contingencies; however, they showed little learning of which X-items went in which frame.

Gough and Segal's main argument against the FSG² as a representation of what was learned is that it is unparsimoniously complex: it has many more rules than the linear grammar³, which I suggested as the most reasonable representation of what the Ss learned. Although the form of argument is convincing in this case, it seems undesirable that the conclusion from the experiment should rest principally on a simplicity argument, where simplicity is determined by a rule count. In linguistic theory and theory of automata, certain kinds of rules are considered inherently more complex than others, and reconstructive memory studies may often, as here, try to show that it is a relatively complex form of rule that is actually learned. Although in practice the difference in number of rules may, as here, be convincingly great, a simplicity argument will often be indecisive when a small number of rules, some of which are complex, is compared with a large number of rules all of which are simple.

I should like to try to find, therefore, an additional form of argument which is acceptable.

In the case of a finite language (and, no doubt, many infinite ones), it seems to me that the most useful general form of argument for or against a hypothetical grammar will have to be based on a comparison of the structural descriptions provided by the grammar with information about the nature of the relationships learned as inferred from behavioral test data. In the present case, the crucial feature of the structural description provided by the FSG is that the X-items are derived from one node (labelled Y) when they occur after a, and from a different node (Z) when they occur after p. Thus the FSG claims that the Ss learn the X-items as two separate lists, once as a list following a, and again as a list following p. However, it seems clear from the data that Ss did not learn the X-items as two separate lists, one for each context, but rather as a single set which went second. It follows that to provide the right structural description, a grammar must give the X-items the same P-marker regardless of context, as in the linear grammar where they always derive from the node X. (Both the transform grammar proposed in Gough and Segal's penultimate paragraph, and the context-sensitive grammar in Note 1 of my article, also provide the same P-marker regardless of context, so this argument does not uniquely support the linear grammar. However, it eliminates all FSGs.) This argument was not included in my original article because there did not seem to be space for it.

The argument criticized by Gough and Segal was based on the fact that a finite state representation of what was learned would have to represent the Ss as having learned 12 rules not used in any of the strings the Ss heard. I argued that Ss could not have learned such a grammar because they did not have the opportunity: they would have to be assumed to have invented these 12 rules. Gough and Segal say that this argument would also invalidate the linear grammar. I cannot agree: every rule of the linear grammar IS exemplified in the input strings. To see that this is so, imagine the following procedure: for any proposed grammar, one considers the input strings in turn, determines which rules of the grammar could be used in the derivation of each string, and places a check mark against these rules. If this procedure is applied to the linear grammar, when the end of the list of input strings is reached, there is a check mark against each rule. If the same

procedure is applied to the FSG, then 12 rules would not receive a check mark. Thus, unlike the FSG, the linear grammar is a function defining an extrapolation from the input set of strings to the set acquired, with all rules exemplified in the input set. (The context-sensitive and transform grammars referred to also have this property.)

In their discussion, Gough and Segal say "The fact is that, strictly speaking, *any* rules which S comes to must be inventions." But there are inventions and inventions! The hypothesis that the relationships learned are those of the linear grammar (or of the transform grammar) assumes only that Ss discover or induce rules; the FSG assumes creation of rules out of whole cloth. Even for the child learning the natural language, it is hard to see that rules could be learned unless they were exemplified in the input, e. g., presumably a child could not learn the passive transform without ever having had any commerce with a passive sentence.

Summarizing the evidence against the FSG as a representation of what was learned, there appear to be four arguments: (1) the FSG is unnecessarily complex; (2) the FSG provides structural descriptions (nodes or P-markers) for the X-items that conflict with the behavioral evidence; (3) the FSG contains rules which are not exemplified in any input strings; and (4) the FSG provides an unreasonable description of the presumed stages of learning—while not reviewed above, this argument is stated in Gough and Segal's last paragraph, and also briefly mentioned in my original article.⁴

Although none of the lines of argument reviewed provide a basis for preferring the linear grammar to the transform grammar suggested by Gough and Segal, there was suggestive evidence against the transform grammar in some data not discussed in my article: the nature of the errors that appeared in the Ss' free recall. The transform grammar claims that the Ss learn the strings in the order abX, pqX (or, Xab, Xpq), and learn also a rule that these orders are to be changed to aXb, pXq. If what Ss learned was this transform grammar, then any incomplete learning of the transform rule would lead Ss to "recall" strings of the form abX, pqX (or Xab, Xpq). Considering all strings having the forms aXb and pXq to be correct, the free recall tests contained 45 errors (36 on the

first test, and 9 on the second). Of these, 15 strings were aXq or pXb, where only the concord is lacking; 16 were aXX, pXX, XXb, or XXq, presumably reflecting partial learning of the positions of the frame items; the remaining 14 comprised seven XXX, two bXp, and one each XXp, XbX, XXa, and qXX. Thus, there was not a single string that could be interpreted as due to incomplete learning of a transform rule,⁵ although there were 31 strings readily interpretable as due to incomplete learning of the phrase structure grammars suggested. While Gough and Segal may well be correct in suggesting that the Ss learn the constituent structure as a...b, or p...q, and X (a point on which the experiment provides no evidence), the data do not support the suggestion that the Ss construct the discontinuity through a transform rule.

References

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- Chomsky, N. Formal properties of grammars. In R. D. Luce, R. R. Bush, & E. Galanter (Eds.), *Handbook of mathematical psychology*. Vol. II. New York: Wiley, 1963.
- Gough, P. B., & Segal, E. M. Comment on "The insufficiency of a finite state model for verbal reconstructive memory." *Psychon. Sci.*, 1965, 3, 155-156.

Notes

1. I am grateful to Gough and Segal for a prepublication copy of their comment.
2. This is FSG-B in Gough and Segal's Fig. 1. It has the rules $S \rightarrow aY, pZ$; $Y \rightarrow x_1 B, x_2 B, \dots x_{18} B$; $Z \rightarrow x_1 Q, x_2 Q, \dots x_{18} Q$; $B \rightarrow b$; $Q \rightarrow q$. ("S" = "sentence," " $\rightarrow$ " = "may be rewritten as," capital letters represent word and phrase classes, and lower case letters represent words.)
3. This is PSG-B in Gough and Segal's Fig. 1. It has the rules $S \rightarrow aXb, pXq$; $X \rightarrow x_1, \dots x_{18}$.
4. Since context-free phrase structure grammars are weakly equivalent to the class of push-down-store automata (Chomsky, 1963), these four arguments for preferring the linear grammar to the FSG are, mutatis mutandis, arguments for preferring a PDS to a finite state diagram model. A reasonable PDS representation of the relationships learned might be: $(a, S_0, e) \rightarrow (S_1, a)$; $(p, S_0, e) \rightarrow (S_1, p)$; $(x_i, S_1, e) \rightarrow (S_2, e)$ for $i = 1, \dots, 18$; $(b, S_2, a) \rightarrow (S_3, \sigma)$; $(q, S_2, p) \rightarrow (S_3, \sigma)$. (See Chomsky [1963, 339ff.] for notation.)
5. Errors reflecting the incomplete learning of a transformation do appear to occur in the learning of the natural language. I have heard young children, notably my three-year-old son, construct questions like "Where Mommy is?", "What Daddy said?" "What Daddy is doing?" "Why you won't let me?" "When Mommy is coming home?" etc. These grammatical "errors" presumably reflect a failure to execute the interrogative permutation transform. The presence of such errors for the natural language suggests that it would be reasonable to expect similar errors in the early stages of learning of an artificial system, if what is really being learned were indeed a permutation transform.