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Aspects of a theory of language acquisition*

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ABSTRACT

This paper presents a hypothesis-testing theory of syntax acquisition. The first section presents our model. We claim that: (1) children learn a transformational grammar, including a set of phrase structure and transformational rules; (2) linguistic universals and Occam's razor constrain the initial hypothesis space available to the device; (3) hypotheses tested by the device consist of candidate phrase structure and transformational rules; (4) linguistic evidence confirms or disconfirms hypotheses. Specific examples of incorrect phrase structure and transformational hypotheses are presented.

The second section briefly surveys other approaches to language acquisition – both syntactic and non-syntactic – and compares them to our model. In the third section, we address several methodological issues: (1) the relevance of linguistic theory to the model; (2) how the model is tested; (3) the domain of the theory.

INTRODUCTION

This paper presents an outline for a theory of syntax acquisition. By concentrating on syntax acquisition we do not mean to deny the importance of other knowledge that is brought to bear in language acquisition. In order to become a successful language user, the child needs to achieve sophistication in a variety of interdependent areas: phonology, semantics, cognition, pragmatics, and so on. However, these related areas supplement but do not supplant syntax. In the first section of the paper we present our model. In the second section we give our perspective on syntactic and non-syntactic approaches to syntax acquisition, showing how our model compares and contrasts with other approaches. In the third section we discuss methodological issues of concern in our model. We conclude that, despite its difficulties, our model is both empirically more adequate and explanatorily richer than other models.

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Our goal is the specification of a learning theory for syntax. Such a theory must detail how the child's syntax learning mechanism acquires the rules that comprise the syntactic component of the grammar of its language. In doing so, it must specify what is innate, what is learned, the nature of the device through which learning is effected, and the role of linguistic experience. Various theorists (Chomsky 1965, Fodor 1966, Katz 1966) have suggested the metaphor of the child as a little linguist who tests hypotheses in order to discover the syntactic rules of his language. A hypothesis-testing device for syntax learning is one which, given its innate properties and the evidence available to it, projects hypotheses about the form of syntactic rules; for theories which take the language acquisition mechanism to be a hypothesis-testing device, the role of linguistic experience is to confirm or disconfirm these hypotheses.

We speak of THE DEVICE here to make clear that we are using the notion of the child as a little linguist or little scientist strictly metaphorically. The child seldom consciously projects and tests hypotheses, whereas the linguist always does. There are many other disanalogies between children as language learners and linguists as grammar writers. The importance of the analogy, aside from suggesting a model of learning, is that we know a hypothesis-testing model is empirically realizable because examples of it, e.g. linguists, exist.

Under the general definition we have offered, many current theories of language learning qualify as hypothesis-testing models. They differ markedly, however, in how they specify the terms of the model. In particular, they differ (1) in what is claimed to be learned; (2) in what the innate properties of the device are; (3) in what the content of the hypotheses is; (4) in what the nature of the evidence is which confirms or disconfirms hypotheses. We now present our specification of the four terms.

A SYNTAX ACQUISITION MODEL

General features

Our hypothesis-testing model resembles most closely the general model suggested by Fodor (1966). Like Fodor's model, our model proposes that the child's hypotheses consist of candidate rules, that the initial hypothesis space is constrained, and that the child's hypotheses are confirmed or disconfirmed by available data.

We specify the four terms of a hypothesis-testing model as follows. What is learned is a transformational grammar. With respect to syntax, the child learns a set of phrase structure rules which generate deep structure representations and a set of transformational rules which map deep structures on to surface structures. What is innate are the linguistic universals, which provide, *inter alia*, the stock of elements and operations for constructing syntactic rules and which constrain the form and function of syntactic rules (Chomsky 1973).

In assuming that the child learns a transformational grammar we are not committing ourselves to any current formulation of that grammar, for reasons related to the discussion below on the joint relevance of language acquisition data and theory to linguistic theory and grammar. The errors we describe below are generally accounted for within an *Aspects*-type grammar (Chomsky 1965, Akmajian & Heny 1975, Baker 1978, Culicover 1976) but could also be accounted for within any of the more current candidate grammars. We use an *Aspects*-type grammar primarily because it is the most widely known.

The content of the hypotheses which the child tests, expressed as candidate rules, is elaborated in the following sections. Hypotheses will be confirmed if they predict some class of (possibly misanalysed) data; they will be disconfirmed if they predict no data and are thus of no use to the child. The role of evidence is also elaborated in the following sections.

The syntax acquisition device must determine the correct formulations of transformational and phrase structure rules. For each case we first present the general content of the hypotheses, and then give a specific example.

Transformational rules

Transformational rules are rules that take as their input a string of abstract syntactic elements and perform some operation(s) on that string. For the purposes of discussion, a transformation can be divided into three parts: the structural description (i.e. the linear string of elements which is input to the transformation), the basic operations (i.e. whether the transformation copies, inserts or deletes elements, or performs some combination of these basic operations) and the structural change (i.e. the linear string that is the output of the transformation). There is dispute over what the stock of basic operations is. On some theories movement is a basic operation; on other theories movement is two basic operations: copying and deletion (see below for further discussion).

For transformational rules, the syntax acquisition device must determine the correct structural description, the correct basic operations, and the correct structural change of the transformation. For example, in order for the child to learn how to form questions correctly it must acquire the rule of subject–aux inversion. That rule may be formulated as follows:

(1) SD:	Q		NP	$\underbrace{\text{Tns}\ (\left\{\begin{matrix}\text{Modal}\\ \textit{have}\\ \textit{be}\end{matrix}\right\})}$	Y
	1		2	3	4
SC:	1	3	2	ø	4

Informally stated, the rule operates on an abstract string which consists of a Q-marker, signifying that the sentence is a question, followed by a noun phrase, followed by a tense-marker, optionally followed by either a modal, *have* or *be*, followed by anything at all. The rule converts that string into one in which tense, plus whichever auxiliary element immediately follows it, occurs before the noun phrase. Later rules will also be necessary, but subject–aux inversion is the main rule of question formation.

From the learning point of view the child's device must determine that $\text{Q NP Tns} \left(\begin{Bmatrix}\text{Modal}\\ \textit{have}\\ \textit{be}\end{Bmatrix}\right) \text{Y}$ is the correct structural description, that copying and deletion are the correct basic operations, and that $\text{Q Tns} \left(\begin{Bmatrix}\text{Modal}\\ \textit{have}\\ \textit{be}\end{Bmatrix}\right) \text{NP Y}$ is the correct structural change. Notice that the operation of moving tense plus an associated verbal element can be described as two operations, one in which the material is copied into its new position before the noun phrase, and another in which the material is deleted from its original position after the noun phrase.

Incorrect hypotheses on the part of the child's device about the structural description, the basic operations, or the structural change of any transformation should result in characteristic errors in child speech (see Valian, Erreich & Winzemer 1979 for a more extended description of predicted errors). For example, in determining the basic operations of a transformation, the device may incorrectly formulate the rule such that it fails to include all of the operations specified in the adult formulation. The linguistic universals specify the stock of basic operations, but not what combinations will obtain in particular rules. Thus, a source for error in the device's formulation of candidate rules is what basic operation(s) the rule employs.

A basic-operations misformulation of copying without deletion could produce the following errors (Mayer, Erreich & Valian 1978 present an extended discussion of these errors), produced by three different children (our data, Hurford 1975, Bellugi 1971).

(A1) Did you came home?	(B1) I did broke it.
(A2) What did you bought?	(B2) Jenni did left with Daddy.
(A3) What shall we shall have?	(B3) I did rode my bike.

The A errors result from an incorrect formulation of subject–aux inversion. Recall that the correct rule of subject–aux inversion copies tense and either modal, *have*, or *be*, if present, into pre-subject position and deletes them from their original post-subject position. The A errors result from an incorrect formulation of subject–aux inversion in which tense (and in A3, a modal) is copied into pre-subject position but not deleted from its original post-subject position. In A1 and A2 a rule of *do*-insertion must apply to attach *do* to the moved and stranded tense marker.

The B errors result from an incorrect formulation of a different rule, the rule of tense-hopping. The correct rule of tense-hopping is formulated as follows:

(2) SD:	X	Tense	V		Y
	1	2	3		4
SC:	1	ø	3	2	4

Informally stated, the rule takes an abstract tense marker that is left-adjacent to a verb, copies it to a position right-adjacent to the verb and deletes it in its original left-adjacent position. The B errors result from an incorrect formulation of tense-hopping in which tense is correctly copied to a position right-adjacent to the verb but is incorrectly not deleted from its original position before the verb. The rule of *do*-insertion must then apply, attaching *do* to the undeleted (i.e. the left-adjacent) tense marker.

Both subject–aux inversion and tense-hopping are incorrectly formulated by these children as copying without deletion, whereas in the adult grammar they are formulated as copying and deletion. Both rules lack one of the operations specified in the adult formulation of the rule. On the basis of our analysis of the above errors, we can make a general statement about one kind of hypothesis the language acquisition device should entertain, namely hypotheses in which the content is a projection about the basic operation(s) of a rule.

We call this the basic-operations hypothesis. One of the predictions of the basic-operations hypothesis is that for any transformation composed of more than one basic operation, there exists a class of errors in child speech correctly analysed as failure to apply one (or more) of the operations specified in the adult formulation of the rule. (For a fuller exposition, see Mayer *et al.* 1978.) The basic-operations hypothesis also predicts that the device will formulate hypotheses involving more or different basic operations than are specified in the adult formulation of the rule, but such misformulations will not be discussed here.

The hypothesis predicts the errors shown in A and B. It further predicts that for any movement transformation there could be errors which are the result of copying without deletion (and of deletion without copying, though such errors are not discussed here). Thus, we predict errors of the following sort in child speech.

Transformation	*Predicted error*
(1) tense-hopping	I did broke it. (Mayer *et al.* 1978)
(2) subject–aux inversion	What shall we shall have? (Bellugi 1971)
(3) particle-movement	The barber cut off his hair off. (Menyuk 1969)
(4) dative-movement	Could you get me a banana for me? (Fay 1975)
(5) *wh*-movement	What did you see what? (not observed)
(6) *ing*-hopping	You could being going to the store. (not observed)
(7) negative-placement	What not can't I do? (not observed)

Errors like (1)–(4) have been reported in the literature, as indicated, while errors like (5)–(7) have not. If errors like (5)–(7) are not found in child speech, their absence, all other things being equal, will constitute disconfirming evidence for our model. This point is discussed at greater length below.

We have discussed potential errors in misformulating rules as if the device were limited to testing only one formulation of a rule at a time. However, just as the scientist may concurrently test two competing hypotheses, so may the child. For example, a child may concurrently use a tense-copying rule and a tense-hopping rule (discussed in Mayer *et al.* 1978) until he is certain that tense-hopping is correct and will handle all the cases that tense-copying handles.

Phrase structure rules

Phrase structure rules generate base phrase markers. They determine both the underlying order of sentential constituents and the hierarchical relations among constituents. Each phrase structure rule takes a single syntactic category and expands it.

For phrase structure rules, the syntax-learning device must determine what syntactic elements are in the domain of the rule, whether they are optional or obligatory, and in what order they occur. For example, one putative phrase structure rule for expanding the auxiliary in English (Akmajian & Heny 1975) is:

(3) Aux → Tense (Modal) (Have+en) (Be+ing)

To learn the auxiliary expansion rule, the device must determine that Tense, Modal, *have+en*, and *be+ing* are the abstract syntactic elements in the domain of the rule, that only Tense is obligatory, and that the elements occur in the above order, all dominated by Aux. For any phrase structure rule the device may incorrectly formulate a rule such that the rule contains the wrong set of elements or contains the elements in the wrong order.

Take, for example, utterances C1–C6, produced by N between 1;9–1;11 (J. Sachs, personal communication). We use them to suggest that N's device analyses *go* on analogy with *be*, namely both as part of the optional expansion of the auxiliary and as a main verb. The analysis is made because *go* shares important superficial features with *be*. The dual analysis of *go* is represented in a partial grammar for N by a rule which expands Aux to optionally include *go+ing* and by a rule of lexical insertion which categorizes *go* as a main verb.

(C1) Going being careful
(C2) Daddy's going taking nap
(C3) Going shopping
(C4) Calves going sleep
(C5) I'm going slide
(C6) Is fish going to work?
(C7) Ing ing ing fall down
(C8) Goes paci in mouth?

(C9) Is this doggie?
(C10) There go horsey
(C11) There it goes

We propose phrase structure rule (4) to partially derive (C1)–(C6) and N's other progressive utterances. (C7) is offered as evidence that N does form progressives by rule, with *ing* as a detached element. Rule (4) will generate (C1) and (C2) if the *go+ing* option is chosen. It will generate (C4)–(C6) if that option is not chosen and *go* is entered as a main verb by another rule instead.

(4) Aux → (Tense) (Be)+ing (Go)+ing

For example, to derive (C2), the device applies the full expansion of (4), along with other phrase structure rules, to produce:

$_{NP}$ [Daddy] $_{Aux}$ [$_{Tns}$ [Pres] [Be+ing] [Go+ing] $_{V}$ [take] $_{NP}$ [nap]

The transformational rules of tense- and *ing*-hopping would then apply to affix tense on to *be*, the left-most instance of *ing* on to *go*, and the second instance of *ing* on to *take*, producing:

Daddy be+Pres go+ing take+ing nap (labelled bracketing omitted for ease of presentation)

After contraction of *be* (which other aspects of N's data suggest is a rule her device uses) and the application of morphophonemic rules, the output would be (C2).

(C1) can be generated if (4) is expanded as *ing go+ing* and *be* is entered as a main verb by another rule. Utterances (C4)–(C6) can be generated if (4) is expanded as *ing* for (C4) and as Tense *be+ing* for (C5) and (C6), with *go* entered as a main verb by another rule. (C1) and (C2), then, employ an expansion of (4) including *go+ing*, while (C4)–(C6) employ an expansion of (4) that does not include *go+ing*.

If N's device has analysed *go* on analogy with *be*, *go* should, like *be*, undergo subject–aux inversion. During the same period that N produced (C1)–(C7), she also produced (C8) and (C9), but never fronted any main verb other than *go* or *be* in asking a yes–no question. Thus, *Goes paci in mouth?* is independent evidence that *go* is analysed like *be*.

Why would N's device analyse *go* like *be*? One reason is suggested by one of N's own utterances: (C10). Except in literary English, the only verb other than *go* which can be substituted in such a frame is *be* (and perhaps *come*). One reason for N to analyse *go* like *be* is that *go* is like *be* in a common sentence frame. That N is responsive to the regularities of the *there* frame is shown by (C11): when a pronoun is used instead of a noun, inversion cannot take place in adult English. N is sensitive to a very subtle regularity, and apparently overgeneralizes from the distributional similarities between *go* and *be* in *there* frames to classify *go* and *be* similarly in other respects, such as including *go+ing* in the auxiliary.

There are other distributional regularities in English which, if N were sensitive to them, would also allow *go* to be included in the auxiliary system as well as serving as a main verb, though somewhat differently from *be*. Again, one of N's own utterances provides a clue: (C3). The *going* X-*ing* frame is also a common one: *going skiing*, *going jogging*, and so on. N's device could take such strings as evidence for an allowed expansion of rule (4), which would analyse them like (C1) and (C2). There is no way of telling from the surface characteristics of such strings that *shopping* is a noun, rather than a progressive form of a verb. Notice, however, that the rules we have attributed to N also allow an analysis of *going shopping* as (C4)–(C6), in which *shopping* can be entered as a noun. There is no way of knowing which derivation N's device actually provides for such constructions.

To summarize our discussion of phrase structure rules, a set of N's utterances suggests that her device has mis-characterized the expansion of Aux as optionally containing *go*+*ing*, as well as correctly labelling *go* as a main verb. The utterances which suggest such an analysis are (C1), (C2), and (C8), with (C3) being ambiguous. Two kinds of distributional regularities in the speech N may be expected to hear give her device grounds for the incorrect expansion of Aux. For one of these kinds of regularities, the *there* frame, N demonstrates her sensitivity to a very subtle regularity concerning nouns and pronouns. Thus it is reasonable to suppose that her device is in fact exploiting the misleading information the *there* regularities provide.

Constraints on the device's hypotheses

In presenting the model thus far, we have given examples of incorrect hypotheses that the device might entertain, but we have said nothing about what limits the initial hypothesis space, nor on what basis the child eliminates incorrect hypotheses. In this section we deal with the role of linguistic universals, evidence, and Occam's razor as constraints on the device's hypotheses.

Universals. The linguistic universals limit the initial hypothesis space (Chomsky 1965, Katz 1966). The child's device will only formulate hypotheses that could be true of a transformational grammar. For example, Chomsky (1965) has suggested that since transformational rules are structure-dependent, the child should never make errors reflecting structure-independent hypotheses. That is, the child should never hypothesize a rule which operates on, say, the second word of a sentence, or the second occurrence of a word in a sentence. Such hypotheses ignore the linguistic structure of a sentence. As another example, the child should project hypotheses about phrase structure rules in terms of syntactic categories like NOUN, VERB, etc., not in terms of semantic categories like ROUND OBJECT, MOVEMENT, and so on.

Occam's razor. We assume that Occam's razor, the principle that one should not needlessly multiply entities or operations, also limits the child's hypothesis space. The child will always project the simplest possible hypothesis that is allowed by

the universals. For example, we earlier presented a formulation of the tense-copying rule. That formulation involved only copying. However, the same output (tense pre- and post-verbally) could have been obtained in a variety of other ways, such as by copying tense into the new position, deleting it from the original position and then re-copying it into the original position. Occam's razor rules out such a possibility because it involves more operations than are necessary to get from input to final output. In general, the same error could always be described as involving the performance of an operation, the performance of another operation which cancels the effect of the first, and then the re-performance of the first operation. Such formulations are ruled out by Occam's razor.

Evidence: confirmation/disconfirmation of the child's hypotheses. The first two constraints limit the child's initial hypothesis space. The primary role of evidence is to confirm or disconfirm hypotheses which are allowed by the linguistic universals and Occam's razor. As the child accumulates knowledge of his language, that knowledge will also serve to constrain the hypothesis space. It should be noted at the outset that evidence is not absolute: it is always interpreted relative to some description made possible by the device's current theory about the language.

In order for the device to maintain a hypothesis which is allowed by the universals and Occam's razor, the hypothesis must predict some portion of the incoming data. Predicted data confirm the hypothesis, while inconsistent data disconfirm it. In the case of correct and only slightly incorrect hypotheses, the data will be accurately predicted and so the hypotheses will be retained.

The question we now address is, what sort of data do incorrect hypotheses predict, such that the device would retain an incorrect hypothesis for any period? As an example, why would the child retain, even for a short period of time, an aux-copying rule rather than a subject–aux inversion rule? Remember that aux-copying generates sentences like *A*, which the child never hears. Further, all past-tense questions, e.g. *Did you like it?* only contain one tensed verb, thus providing further evidence against the rule. There are, however, classes of grammatical data which an aux-copying rule predicts, on the assumption that the rule forces a misanalysis of surface structure.

When a child hears an utterance, he must pre-analyse it before he can apply syntactic and semantic rules, because rules operate not on a sequence of sounds but on a sequence of abstract categories. That pre-analysis is dependent on prior rule-learning. If a child has a rule of aux-copying, he might misanalyse a sentence like *Do you like it?* as V+Pres NP V+Pres NP. The untensed form of *like* can consistently be interpreted as a tensed form in the present tense, except for third person singular. In fact, all verbs but *be* have a present tense form which is identical to their untensed form, except for third person singular. Thus, present tense questions provide the device with evidence for an aux-copying rule, under the misanalysis which that rule makes likely. (Under the analysis directed by the correct rule of subject–aux inversion, present tense questions will be seen as having an untensed main verb, and will provide evidence for the correct rule.)

Since an aux-copying rule predicts data, a child may retain it. Note that in order to produce errors like *Did you came home?* the child must generalize from cases that the rule predicts (i.e. present tense cases) to cases where the evidence contradicts the rule (i.e. past tense cases). Note also that the child may produce correct sentences like *Do you like it?* with an incorrect aux-copying rule. It is only in the present tense third person singular and in the past tense that his error would be apparent to the investigator from the surface form of the utterance. As evidence which is contradictory to the aux-copying rule mounts, the child will abandon it in favour of an inversion rule: an inversion rule predicts both the set of data predicted by the incorrect copying rule and the data which the copying rule cannot handle.

The reformulation of the aux-copying rule will also force a re-analysis of the surface structure of main verbs in present tense sentences. In those cases where the main verb had been analysed as V+Pres it will now be analysed simply as V. Similarly, if the child's device misformulates the phrase structure rule for expanding the auxiliary such that it optionally contains the element *go+ing*, the gerund in sentences like *I am going shopping* will be misanalysed as V+*ing*. The reformulation of the auxiliary expansion rule entails a re-analysis of the structure of *shopping* from V+*ing* to NP. As rules change, so will surface structure analyses. As correct surface structure assignments are established, they will serve to limit future possible hypotheses about rules. Conversely, as correct rules are established, they will serve to limit possible variation in future surface structure assignments.

Our discussion of evidence suggests a reason for the child to have competing hypotheses about rules: some class of available data may be ambiguous in that more than one formulation of a rule could generate the sentences in this class. This is the case with sentences like *Do you like it?* and *Do you want it?*; these sentences could be generated by either an aux-hopping or a subject–aux inversion transformation. The device may entertain both hypotheses simultaneously until a later point when it selects the tense-hopping rule.

Stated more generally, in order for two rules to be in competition the sets of data that each predicts must intersect. That is, there must be some class of data that could be generated by both of the rules. The device must determine which rule is correct for this class of data.

Formally stated, the necessary and sufficient conditions for two rules to be in competition are as follows: (*a*) for transformations, both rules must have the same structural description but different structural changes; for phrase structure rules, both rules must have the same symbol on the left-hand side but different expansions on the right-hand side; (*b*) for transformational and phrase structure rules, there must be a class of sentences that could be generated by both competing rules. Conditions (*a*) and (*b*) are each necessary but only jointly sufficient for two rules to be competing. Our definition of competing rules may be so restrictive that few rules will satisfy the joint conditions. In order to describe more of the child's rules, it may thus be necessary to define a broader class of conflicting rules, in which one or both of the conditions is relaxed.

There are relatively few rule-related errors apparent in child speech. We now offer some speculations about why this is so. There are two categories of rules which when misformulated by the child lead to consequences of differing seriousness. First, there are rules which interact with other rules. For example, in the derivation of questions, a child's grammar could not contain both a subject–aux inversion rule and a tense-copying rule whose domain of application includes questions. Employing both rules in deriving questions would result in ungrammatical sentences like *Does is it upstairs?* The error would result because subject–aux inversion copies Tense and *be* into pre-subject position and deletes them in post-subject position; tense-copying copies Tense onto *be* but does not delete it from pre-verb position, thus necessitating *do*-insertion. Since none of the data that the child hears is consistent with this formulation, the child would be forced to give up a tense-copying rule in questions. Thus, the way subject–aux inversion and tense-copying interact forces the incorrect tense-copying rule to be abandoned in forming questions. The tense-copying rule could still be maintained, but its domain of application would be restricted to non-questions where there are data that the rule predicts. Rule interactions will force correct formulations, resulting in errors with a relatively short life.

Secondly, there are rules which have minimal impact on other rules, such as number agreement or the morphophonemic rules that apply to irregular verbs. The most prevalent errors in child speech are those which are due to incorrect formulations of this second type. We suggest that this is so because in the first type disconfirming evidence accumulates more quickly, thus forcing the rejection of incorrect hypotheses about rules. Incorrect hypotheses about rules which minimally affect other rules will be retained longer because there is little pressure from other parts of the grammar to reformulate them and because their maintenance often allows for a simpler system – one with fewer exceptions. Thus it is not surprising that the most frequent errors in child speech are those that violate local syntactic or morphophonemic realization rules. Incorrect hypotheses about, for example, the past tense forms of irregular verbs are disconfirmed slowly because the correct forms can only be acquired in a piecemeal fashion, with the acquisition of each form being relatively independent of the acquisition of any other; in contrast, a misformulation of a rule like passive, because it is so interdependent with other rules in the system, receives disconfirmation from many different sources.

We conclude our section on evidence with a brief discussion of parental speech. Recently a good deal of attention has been focused on parental speech as a potential teaching language. If the data to which the child is exposed are ideal, the argument runs, the need for sophisticated and constrained initial hypotheses on the child's part is reduced (Snow 1972, Levelt 1975). The argument is invalid, however, because what counts as an 'ideal' or 'simple' set of data cannot be specified outside of a theory of acquisition. A theory of the mechanism defines what ideal or simple data are.

A mechanical analogy may be useful here. If we are presented with a perfectly running well-tuned engine and want to determine what kind of fuel it requires, four points become clear. First, whatever fuel the engine is presently getting must be at least adequate or it would not run perfectly. Secondly, what fuel type is ideal for one kind of engine will be non-ideal for another. What counts as ideal depends on the construction of the engine. Thirdly, there is no way of knowing which properties of the fuel the engine is getting are the important ones (assuming for the sake of argument that we know how to analyse the fuel) without knowing how the engine is constructed. Fourthly, no fuel can allow an engine to perform better, or perform more functions, than its construction allows. The moral is that ideal input can only be specified relative to the system it is input to.

In the case of language acquisition, without a theory of how the device is constructed, 'ideal' tends to be equated with 'simple', and 'simple' tends to be equated primarily with 'short' and 'devoid of hesitations'. Given our model of the device, it needs evidence to evaluate its hypotheses against, and so the ideal input is a representative sample of sentences and construction types. Along similar lines, Fodor (1966) suggested that the view that parents could make language learning easier by simplifying the syntax of their speech to children, hence limiting the child's access to data about his language, might in fact make it hard for him to learn the correct syntactic analysis of the language. Rules which have been formulated to apply to a subset of simple sentences may have to be reformulated to accommodate more complex sentence types.

Newport, Gleitman & Gleitman (1977) have shown that although parents' speech generally contains utterances which are shorter and more intelligible than those to adults, it is also characterized by utterances which are more transformed than are utterances to adults. The speech to children also includes more examples of imperatives, *wh*-questions, *yes–no* questions, and deictic questions than does speech to adults, and correspondingly fewer examples of declaratives. Although Newport *et al.*'s observations were confined to basic sentence types (questions, declaratives and imperatives), the phenomenon of more equal representation may be repeated with more fine-grained construction types. If so, the data the child receives are well suited to a hypothesis-testing device.

Concomitant with our emphasis on representative data is a de-emphasis on frequency of sentence types as a determining variable. If the data the child hears are representative of the language as a whole (within the limitations imposed by shorter length), then many constructions will occur just a few times each. Consequently, frequency should not be an important variable. The importance of frequency as a variable has been little studied, but Brown (1973) reports that children's mastery of morphemes does not correlate with the frequency of those morphemes in parental speech. Further, Newport *et al.* were unable to confirm frequency of occurrence as an important variable in most aspects of acquisition.

Thus, our assumptions about the character and importance of the data the child receives are somewhat supported by the literature. The data are 'ideal' from the standpoint of a hypothesis-testing device, without this implying that the device is any less richly structured.

Summary of constraints. Our model provides for three constraints on the child's hypothesis formulation and maintenance: linguistic universals, Occam's razor, and evidence. Universals rule out hypotheses which would be formulated in terms of variables irrelevant to syntax. Occam's razor rules out all but the simplest hypotheses allowed by the universals. Evidence determines which hypotheses will be retained and which will be jettisoned quickly. Hypotheses which are allowed by the universals but which are far off the mark will be quickly disconfirmed; the hypotheses that the child is likely to maintain are those which are closest to being correct, because little evidence is contradictory.

COMPARISON WITH OTHER APPROACHES

We will now contrast our model first with other syntactic approaches, then with non-syntactic approaches, using the four terms of a hypothesis-testing model as the comparison points.

Syntactic approaches

Grammar-writing. Our model is most closely related to the work on syntax acquisition begun in the 1960s and inspired by transformational grammar (Brown, Cazden & Bellugi 1969, Klima & Bellugi 1966, Bloom 1970, McNeill 1970). Our similarities lie in our common claim that what is learned is characterized by a transformational grammar and that what is innate are linguistic universals. Our differences with the grammar-writing approach lie in our explicit claims both about the content of the hypotheses the child tests (which take the form of candidate rules) and about the rule of linguistic experience in that testing.

In general, the work in the 1960s focused on describing successive stages of the child's speech output, using a phrase-structure or transformational grammar. The approach had only limited success because it did not provide an account of the principles which underlay syntax acquisition. A deeper account would both explain the sequence of stages within a child and would allow generalizations to be made across children. Bloom's (1970) grammars for three different children, for example, are quite different; they have elements in common, but it is not clear what the importance of the commonalities is.

Rather than trying to write successive grammars, our approach uses the partial grammars of several children to get evidence about the underlying mechanisms of acquisition. Partial grammar-writing is a means of determining what hypotheses the device is testing; it is not an end in itself. Changes in child grammars are, on our theory, a consequence of continuous hypothesis formulation and testing. Grammars change when hypotheses about rules are disconfirmed and new hypotheses are formulated. Thus, the continuity is not at the level of grammars but at the level of hypothesis testing. Similarities across children will not necessarily be stated in terms of which rules are acquired when, but in terms of how all rules are acquired.

Order of acquisition. The order of acquisition approach investigates the order in which children acquire various syntactic structures and constructions. A catalogue of the stages of language acquisition is lacking in two respects. First, there is, as with grammar-writing, no account of why the stages progress as they do (e.g. Crystal, Fletcher & Garman 1976); our model, on the other hand, is concerned with the basic principles according to which hypotheses will be formulated and tested. Secondly, even when there is an attempt at such an account (e.g. Brown 1973, with his suggestion of syntactic or semantic cumulative complexity), it is questionable whether the appropriate structures are being accounted for in the first place. For example, Brown's (1973) taxonomy of grammatical morphemes divides the acquisition of the past tense morpheme into a regular verb category and an irregular verb category. However, a transformational grammar contains only one tense movement rule and it applies to all verbs which are marked for tense. The variation which occurs in learning the correct inflections for regular and irregular verbs need not reflect different hypotheses about a tense rule on the child's part, but different degrees of mastery of how tense is phonologically 'spelled'. Two different things need to be learned; one is a transformational rule and has no exceptions; the other is a set of morphophonemic rules and has many exceptions.

Since the previous order of acquisition approaches tend to be theory-neutral, it is not clear what, if any, claims are made about what the end-point of learning is, about what the innate properties are, about what the content of the hypotheses is, or about how evidence plays a role in confirming and disconfirming hypotheses.

A more recent order of acquisition approach is taken by Roeper (1978), Solan (1978), Tavakolian (1978), Goodluck & Roeper (1978) and Lust (1977). These investigators assume, as we do, that not only do children learn to make

surface structure generalizations, they also learn the full panoply of rules and systems of interpretation specified by a transformational grammar. We differ from these investigators in that our primary concern is with developing a theory of the acquisition mechanism. Our interest in particular rules is only to aid in the development of an explanatory model.

Acquisition in linguistic theories. Wexler, Culicover & Hamburger (1975) and Wexler (1978) focus on learnability, i.e. constraints on grammars such that they are learnable; however, a specification of learnability principles (technically defined) does not dictate how learning is actually effected. In contrast, we are concerned with the syntax-learning mechanism. Chomsky (1975) conceives of the grammar being selected from the set made available by universal grammar. One way of viewing our model is as the mechanism by which selection takes place, namely, hypothesis-testing.

Surface structure generalizations. This approach contrasts with our model primarily in what is claimed to be learned and what is claimed to be innate. On this approach, as in ours, the child learns how to assign grammatical categories, learns surface structure distributional facts, learns how to assign constituent structure, and learns about lexical entries. (See Braine 1963, 1976, Kuczaj 1976, Prideaux 1976, Maratsos 1978, in press, for illustrations of the surface structure generalization approach, and Fay 1978, Mayer *et al* 1978 for criticisms of it. See also Derwing 1973, 1977 for extensive claims about the inappropriateness of transformational grammar as a model of what is learned, and of linguistic universals as a correct description of what is innate.) In addition, however, we claim that the child learns a full transformational grammar. The basis for our more extensive claim about what the child learns is the inadequacy of surface structure generalizations alone to account for adult competence (Chomsky 1965, Postal 1968, Katz 1971).

As to the innate component of the language acquisition device, our model projects a correspondingly richer structure. We make the claim that the innate givens constrain the formulation of transformational hypotheses as well as hypotheses about surface structure properties.

Non-syntactic approaches

Cognitive basis. What our model generally has in common with the syntactic approaches is that the child learns syntactic rules which are considered independent of, rather than derivable from, principles of cognitive structure. In contrast, many current theories of language acquisition assume that syntactic entities (e.g. syntactic categories and relations, the hierarchical structure produced by phrase structure rules, rules which relate underlying and superficial structure) do not derive from innate linguistic structures, but are learned after an interaction between cognitive structures and experience takes place. Cognitively based theories vary enormously. There are suggestions about the child's self-instructions on how to learn (Slobin 1973), in which certain cognitive structures are seen as necessary prerequisites for language. There are suggestions that the child's cognitive structures provide not just a necessary but a sufficient source for all of language learning (Schlesinger 1977). (Cognitively based theories have also been proposed by Sinclair 1971, 1973, Goodson & Greenfield 1975, McNeill 1975.)

Our approach differs from the cognitively based models in terms of what is innate (on our model, linguistic and cognitive universals; on cognitive models, only cognitive universals), in the content of the rules (on our model, specific linguistic formulations, which are derived from what linguistic universals make possible; on cognitive models, cognito-linguistic formulations, in which analogies to the linguistic mode are derived from the cognitive principles), the nature of confirming/disconfirming evidence (on our model, linguistic input which, analysed according to the child's current grammar, acts to confirm or disconfirm candidate rules; on cognitive models, anything from language-particular entities such as the 'ends of words' (Slobin 1973) to experiential events which, in effecting changes in cognitive structure, somehow vaguely reflect themselves in linguistic structure), and, for some theories, in what is learned (on our model, transformational grammar; on some cognitive models, 'cognitive' grammar or 'case' grammar).

Within our approach, the main criticism of cognitively based theories is that the cognitive principles are stated so generally that there is no way of testing the claim that syntactic rules, categories and conditions derive from cognitive principles. No one has taken a rule of English or a syntactic universal and shown why it, and only it, derives from a combination of cognitive principles and experience. (See Valian 1977, 1979 and Roeper 1978 for criticisms of some of these theories.)

Strategies. In a strategy approach put forth by Bever (1970), the child is born with the linguistic universals, and learns a transformational grammar, but does not use that grammar for the purposes of talking and listening. For talking and listening the child develops another system, a system of strategies which map sound on to meaning. Strategies derive from general cognitive principles which are specialized for linguistic use. The strategies Bever has detailed are at present inadequate to characterize our range of talking and listening abilities; it is not clear if more strategies could close the gap, or whether a transformational grammar would eventually have to be appealed to. If strategies are likened to hypotheses, they are not so much hypotheses about rules as they are hypotheses about procedures to follow in talking or listening. Like all procedures they assume certain knowledge stores such as what a noun is. It is left unclear as to what sort of evidence is crucial to the formulation of these strategies.

METHODOLOGY

Relevance of linguistic theory to the model

One possible reason for the demise of transformationally based psycholinguistic models is uncertainty as to the correctness of the grammars which the psycholinguistic models assume (Valian 1979). In this section we address that problem directly and show that errors in the assumed grammar can range from having minimal consequences for our model to having major consequences.

We start with the mistakes that have minimal consequences. Under our assumptions, the correct grammar of English specifies the phrase structure and transformational rules that the English-speaking child must eventually learn. It is a consequence of our theory that one of the ways a child will misformulate a transformation is in terms of a subset of the possible basic operations. However, the ways in which a child may initially misformulate a rule are in no way contingent on the adult formulation of that rule; i.e. within the constraints imposed by linguistic universals, a child's first formulation of a rule may be exactly right, close to correct (copying without deletion for a rule that requires copying and deletion), or very wrong (copying for a rule that requires insertion). If the candidate grammars currently available are incorrect in their specification of a particular rule, then our model will incorrectly specify how the child's formulation is divergent from the adult's correctly formulated rule; however, our account of the child's formulation will remain essentially intact.

An example concerning the correctness of candidate English grammars is the problem of *do*-support; the issue is whether there is a rule of *do*-insertion in which *do* is not present in deep structure but is transformationally inserted, or a rule of *do*-deletion, in which *do* is present in deep structure but is transformationally deleted. Our model has assumed that the child has a rule of *do*-insertion. Our attribution of *do*-insertion to the child's device could be accurate even if the adult rule is *do*-deletion. Exactly the same reasons that have led many linguists to postulate *do*-insertion could lead the child to postulate it initially, only later to relinquish it in favour of the correct *do*-deletion rule. (See Akmajian & Heny 1975, Baker 1978, and Culicover 1976 for presentations of both analyses.) We expect the child to formulate incorrect rules. Thus, we cannot draw logically valid inferences from the child's rules to the adult formulation of rules, nor from the adult formulation to the child's initial and intermediate rules.

We turn now to a more serious source of errors for acquisition models, errors in universal grammar. Universal grammar specifies what the building blocks of the child's hypotheses are. It specifies, in other words, what innate properties the device possesses. Errors in candidate formulations of universal grammar will therefore be directly reflected by errors in acquisition theory. The magnitude of the consequences of such errors for acquisition theory as a whole will depend on the magnitude of the errors in universal grammar formulations. The consequences can be more or less serious.

An example of a less serious consequence concerns our assumption that copying and deletion are each a basic operation, and hence are two of the building blocks out of which the child constructs candidate transformational rules. It could be that copying and deletion are not basic operations. But even if that were so, the consequences for the theory would be limited to the necessity to re-describe the errors. The same apparatus could be used; instead of copying and deletion, we would plug in their replacements. Whatever the basic operations are, they will have to account for at least the same linguistic facts as the present candidates do, unless there is no such thing as a basic operation.

If there were no such thing as a basic operation, our assumption that there is would be an error of very serious consequence. A crucial part of our acquisition theory would be misguided and without foundation if basic operations are not linguistic universals. Note, however, that if our theory is able to predict facts about acquisition, it provides evidence for the universals that it assumes. That is, to the extent that basic operations prove explanatory in language acquisition, their status as a feature of universal grammar is supported. Conversely, to the extent that features of universal grammar are explanatory in linguistic theory, their status as constraints on syntax acquisition is supported. Language acquisition data and universal grammar are thus reciprocally relevant in a way that language acquisition data and particular grammar are not. Work on universal grammar and work on language acquisition go hand in hand.

How the model is tested

The basic way any theory is tested is by seeing if the claims it makes are true. The principal claim of the hypothesis-testing model we have proposed is that all children learn the syntactic rules of their language by formulating and testing candidate rules against evidence, using the linguistic universals as the hypothesis source. All that is needed to falsify the claim is the existence of one child who does not have the stipulated mental representations and processes; hence, the claim is empirical and falsifiable in principle. It is not open to the most direct and ideal test, however, because it is impossible to look directly into a child's mind to get evidence for or against the model. So we must devise more easily tested empirical claims.

Thus far we have confined our claims to predictions about classes of errors in child speech, and have concentrated on basic-operations errors, especially in movement rules. (Movement rules comprise the largest class of transformations in English and hence are a particularly appropriate rule type to concentrate on.) We have claimed, in effect, that rule types will 'attract' certain errors in the course of acquisition. *Ceteris paribus*, all movement rules should attract copying-without-deletion errors and deletion-without-copying errors. Put another way,

ceteris paribus, for each movement rule, averaging across all child speech, there should exist basic-operations errors. In statistical terminology, rules are treated as the random effect and children are treated as the fixed effect. In logical terminology, the claims are universalized across rules, not across children.

We have not claimed that every child will make basic-operations errors in learning every movement rule, or even in learning any movement rule. Nor have we made any claims about the order of rule acquisition. It is a defect in the model that the claims are currently as limited as they are. We now briefly discuss why the claims are limited, and then turn to the question of how well the theory fares with the limited claims it currently does make.

There are two main reasons we are currently unable to make claims about every child's BEHAVIOUR. The first is that we do not know enough about how acquisition theory interacts with use theory. For example, it could be the case that children are highly conservative speakers: in speaking they might use a combination of essentially non-syntactic strategies plus those syntactic rules which have been highly confirmed by evidence, testing their hypotheses via *Gedanken* experiments. In that case, few syntactic errors of the sort we predict would occur per child. Or, it could be the case that there is large variability in the extent to which children use less highly confirmed rules, so that some children will produce many more errors of the sort we predict than other children.

The second reason is that there are many non-linguistic factors that may determine order of rule acquisition, and consequently other aspects of child speech as well. For example, a very curious child might find it useful to master the rudiments of asking questions early, a demanding child imperatives, and so on. Until the many non-linguistic variables which interact with syntax acquisition can be factored out, it seems premature to make predictions about each child's behaviour.

At present, then, the model predicts the existence of basic-operations errors for transformations. As a particular example, *ceteris paribus*, for all movement rules there should be examples of copying-without-deletion errors. The *ceteris paribus* clause is necessary because our theory predicts that there are two cases in which errors would not be expected: (1) if there is no linguistic evidence to confirm the incorrect rule; (2) if prior knowledge is inconsistent with the incorrect rule. The prior knowledge may either take the form of a linguistic universal or of previously learned linguistic facts.

How well does the theory fare? Confirmation occurs if the predicted errors are found. Disconfirmation occurs if (1) the predicted errors are not found or (2) errors that are not predicted are found. We have previously discussed basic-operations errors that do occur. There are other errors, such as *What did I see what?*, involving copying without deletion of *wh*-words, that have never been reported in children or adults. There is no grammatical English sentence in which the same *wh*-word appears both sentence-initially and sentence-finally simultaneously, and therefore no linguistic evidence to confirm such a rule. It is, however, still a mark against the theory that not a single such error has ever been noticed.

In addition to predicted errors being absent, there are also existent errors which are not predicted, although they superficially seem predicted. For example, errors of copying without deletion have been reported for particle movement, thus appearing to confirm the theory, but there is no linguistic evidence to support such a misformulation, except for sentences like *I'll look up Jane up in Boston* and *she's sending in her application in two days from now*, where the rule would assign a mistaken surface structure analysis, treating the preposition as a particle. It is unlikely that children ever hear such sentences. Thus, unless a convincing argument can be made that such errors have another well-motivated source, their existence is disconfirmatory of the theory.

There are yet other unpredicted errors. *It don't had a map* (Kuczaj 1976), for example, cannot be explained in terms of incorrect formulations of phrase structure or transformational rules. If such errors are syntactic then our model is disconfirmed. If the errors can be correctly assigned to another linguistic domain, such as the lexicon, the errors would not be evidence against our model. It is unclear what kind of error is represented in *It don't had a map*, and hence its status as a counter-example is also unclear.

In summary, the theory is faring middling well. It predicts some data and is disconfirmed by other data. The results seem encouraging enough, especially in the absence of any competing theory which fares any better, to continue elaborating and refining the theory.

Domain of the theory

Our model has analysed children's errors as the outcome of incorrectly formulated rules. That is, our theory is a learning theory and therefore attributes imperfect knowledge or competence to the child until the end-point of learning is reached. It is possible, however, to use the same apparatus that our model uses and attribute the errors not to incorrect hypotheses but to incorrect applications of a correctly formulated rule (as we do for adults in Valian *et al.* 1979). That theory would assume correct competence (with learning left unaccounted for), but imperfect performance on the child's part.

Foss & Fay (1975) have presented such a performance model. They argue that copying without deletion errors result from a performance limitation on the number of operations a child can perform in producing utterances. The child has the correct movement rule formulated, but fails to delete in order to reduce the number of operations to be performed. Thus, they predict that operations will be omitted in sentences which require many operations in their production.

Although Foss & Fay's (1975) particular analysis cannot account for our data (see Mayer *et al.* 1978, for a refutation of their particular arguments), we, like Foss & Fay, expect performance errors in child speech. Children, like adults, ought to speak strings which are ungrammatical from the point of view of their own grammars. Thus, although we can show that some copying without deletion errors could not result simply from a limitation on the number of operations a child can perform, there may be other performance accounts which will work.

Fay (personal communication), for example, has suggested that a performance model which assigns different costs to different basic operations, or weighs number of operations within a rule differently from number of operations in two successive rules, might predict our and other errors. Another possibility is that number of operations is irrelevant; instead, number of symbols used is important. Simpler rules have fewer symbols. On that analysis, copying and movement rules are equal because they both involve the same number of symbols (counting the null symbol, ø, as a symbol).

For any individual case it is difficult, perhaps impossible, to decide whether the error is due to performance limitations or to an incorrectly formulated rule. In general, we would expect no systematic variability within a rule for performance errors: they ought to occur across all rules or operations, and should always occur whenever a particularly unfavourable constellation of performance factors occurs. Competence errors, in contrast, should cluster both within a rule and in time. They should virtually disappear once the rule in question is fully learned.

The most important difference between a competence model and a performance model, where both use rules as theoretical entities, concerns the domain of the two models. A competence model explains acquisition of rules; it says nothing about how rules are used. A performance model explains use of rules; it says nothing about how rules are acquired. Neither model alone is adequate to explain a child's behaviour, since children both acquire and use rules. Both models are necessary, which has as a likely consequence that some errors will be errors of competence and others errors of performance. The question becomes not one of which model is right, but one of how the two models interconnect.

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