2. The resilience of recursion: a study of a communication system developed without a conventional language model

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2.1. Constraints on human language learning

The facts of human language learning suggest that we are not free to acquire all types of communication systems at all times during our lifespans. There is evidence that a human must learn a language within some critical developmental *time* period (Lenneberg, 1967). Moreover, there may be constraints on the *type* of language learned as well. All of the languages acquired by humans, although apparently different on the surface, share numerous properties at deeper levels of analysis (Bach & Harms, 1968; Greenberg, 1966). This may suggest that languages with properties differing radically from this set would be difficult, if not impossible, for a human to acquire.

Constraints of a similar nature appear in the communicative behaviors of many species (Mayr, 1974). For example, in order to develop his song, the white-crowned sparrow must receive acoustical experience sometime between one week and two months after hatching (Marler, 1972). Before and after this critical period, the sparrow is not "open" to environmental experience and can make no use of it even if it is available.[1] Further, there are constraints not only on the time during which song may be learned, but also on the type of song that can be acquired during that period. A sparrow exposed only to the song of another species will develop no song rather than an alien song. Thus, even during his critical period, the sparrow is only partially "open" to environmental effects and can incorporate only certain types of information.

The white-crowned sparrow is predisposed to acquire the white-crowned sparrow song. Pushing this phenomenon further, it turns out

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that the sparrow may be more predisposed to acquire certain properties of this song than others. At less-than-perfect learning times (specifically, at the edges of his critical period), the bird seems to be able to acquire only a subset of the properties of the species song. With exposure to normal song between the fiftieth and one-hundredth day of life, the sparrow can acquire a song with some of the general structural properties of his normal song (i.e., with the expected division into whistle and trill portions), but without the detailed syllabic structure of the normal song (Marler, 1972). Thus certain properties of the sparrow song seem to be *resilient* and can withstand variation in learning conditions, whereas other more *fragile* properties cannot.

Seligman and Hager (1972) have defined the notion of "preparedness" in terms of parameters of this type, that is, in terms of acquisition under variations in learning conditions. A behavior that can be acquired under degraded input conditions is said to be more prepared than a behavior that cannot be acquired (or can be acquired with less ease) under the same degraded conditions. In this sense, the white-crowned sparrow's whistles and trills are prepared song behaviors, whereas his syllabic structure is a less prepared behavior. Prepared behaviors would be expected to appear under widely varying learning conditions, but unprepared behaviors would appear only under more specialized and enriched conditions. Given natural variations in the environment, prepared communication behaviors ought to appear more reliably than unprepared behaviors in each species-member's communication system. As a result, the more prepared a communication system, the more constrained would be the features of that system; but at the same time, the more prepared the system, the *fewer* would be the constraints on the external conditions necessary to develop that system.

Degrading linguistic input. A search for the "prepared" or "closed" properties of human languages can reasonably begin by degrading linguistic input conditions and observing the subsequent course of language development. As in studies of the sparrow, those properties developed under the degraded input conditions (i.e., those more immune to the vagaries of the environment) can be considered the prepared linguistic properties; those not developed under these same conditions are clearly more susceptible to environmental variation and, in that sense, are less prepared.

We can degrade input conditions either by manipulating the time of acquisition (i.e., by observing language learning outside the critical period) or by manipulating the quality of the linguistic input during acquisition (i.e., by observing first-language learning during the critical period but with a degraded linguistic model or with none at all). Ethical considerations prevent us from deliberately creating human situations of either type. However, tragic circumstances and nature itself have fashioned language learners in both types of situations.

At the age of 20 months Genie was confined to a small room and allowed no freedom of movement, no perceptual stimulation, and no human companionship until she was discovered at the age of 13 years, 7 months. This age is generally taken to be outside the critical period for human language learning (Lenneberg, 1967). Under such conditions of extreme deprivation and isolation, it is hardly surprising that Genie did not develop language during the first thirteen years of her life. More relevant to the discussion here is Genie's linguistic progress after her discovery.

When she was discovered, Genie's linguistic skills were minimal. She appeared to be able to comprehend a small number of single words, but gave no evidence of understanding syntax and never spoke. Over the next five years, she made considerable linguistic progress (Curtiss, 1977), an achievement which suggests that human language learning can take place beyond the critical period. However, as was the case with the sparrow, Genie was able to learn certain properties of language (e.g., word-order production rules, constituent structure, recursion) but not others (e.g., pro-forms, movement rules, auxiliary structure; see Section 2.5 for further discussion).[2] Those properties of language which Genie did learn are good candidates for the resilient properties of language, the ones that humans may be prepared to learn; those properties which Genie has not yet learned are good candidates for the fragile language properties, the ones that humans may be less prepared to learn.

The second class of experiments investigating constraints on language learning involves depriving an individual of normal linguistic input during his critical period. Genie herself provides an example of such a study. However, the deprivation Genie experienced was so extreme, involving much more than just linguistic deprivation, that little positive can be said about the human propensity to develop language on the basis of Genie's inadequate language development. Nevertheless, Genie's case does convince us that there are limits on the conditions under which humans can develop language, and that Genie's language-learning conditions, not surprisingly, exceeded those limits.

The population of deaf children of hearing parents that my colleagues and I have been studying for the past several years provides another example of degraded linguistic input, in this case with no other forms of deprivation, during the critical period. These children have hearing losses so severe that they can make no natural use of the oral language that surrounds them; moreover, these particular children have not been exposed to conventional manual languages (e.g., Signed English, American Sign Language) and instead are being trained orally (i.e., trained to lip-read and to produce sounds through kinesthetic cues). At the time of our study, the children had made little, if any, significant progress in their oral training. Thus, for all intents and purposes, these children were lacking conventional linguistic input in both oral and manual modalities.[3]

Despite these degraded linguistic input conditions, each of the six children we have studied has developed a gestural system that has many, but obviously not all, of the properties of human natural languages (Feldman, Goldin-Meadow, & Gleitman, 1978; Goldin-Meadow, 1979; Goldin-Meadow, in press; Goldin-Meadow & Feldman, 1977). For example, the children have developed lexical items of two types.[4] First is the nounlike *deictic sign* used to refer to people, places, and things (e.g., a pointing gesture that relies heavily on context for interpretation, analogous to *that* or *there* in the speech of a comparably aged hearing child); semantic case roles, such as patient, actor, and recipient, are conveyed by these deictic signs. Second is the verb/adjectivelike *characterizing sign* used to refer to actions and attributes (e.g., a pantomimed action or trait such as a fist held at the mouth, accompanied by chewing, to signify "eat," or the index finger and thumb forming a circle in the air to mean "round"); predicate functions, both action and attribute, are conveyed by the characterizing signs.

In addition, these lexical items are concatenated into *sign sentences* expressing the typical semantic relations found in normal child speech. These sign sentences conform to syntactic rules of two types. Sign-ordering rules describe where in the surface structure of a sentence a particular case or predicate will tend to be signed (e.g., signs for the patient, or object acted upon, tend to precede signs for the act; for instance, point at bicycle precedes two fists "pedaling" in the air, transcribed as "bicycle-PEDAL"). Production probability rules describe the likelihood of a particular case or predicate's being signed in the surface structure of a sentence (e.g., patients are most likely, actors least likely, to be signed; that is, the patient "curds and whey" would be more likely to be produced in a sentence about eating than would the actor "little Miss Muffett").

Finally, the children produce sign sentences whose surface structures are systematically related to underlying structure. For example, the *actor* is more likely to be signed in the surface of a sentence with a two-term underlying thematic structure, such as a sentence about dancing, "elephant-DANCE," than in a sentence with a three-term underlying structure, such as a sentence about eating, "apple-EAT," and is even less likely to be signed in a sentence with a four-term underlying structure, such as a sentence about transferring objects, "box-GIVE" or "GIVE-me." These language properties, developed without a conventional language model, can reasonably be considered to be resilient properties of language.

In this chapter I suggest that recursion, an important property of all natural languages, may also be a resilient property of language. Recursion provides a language user with the means for expressing more than one proposition in a single sentence. I describe data, primarily from one deaf

child of hearing parents (David), on two-proposition sentences developed without a conventional linguistic model. After first describing the types of conjoined sentences David has produced, I look at evidence for underlying structure in these conjoined sentences and explore the nature of this structure. Finally, I summarize the findings on a sign system developed with degraded linguistic input in terms of constraints on language learning in humans.

2.2. Recursion in a language developed under degraded input conditions

The data

The data for this report come, for the most part, from the most prolific subject, David, who over the course of the study produced roughly 350 complex, two-proposition sentences. In contrast, the other five deaf children in our original study as a group produced only 40 such sentences. Whenever numbers permit, the data from the other five children will be cited to supplement David's data, but, in general, this is the story of recursion in David's sign system.

The data were gathered over a period of two years during thirteen sessions, beginning when David was 2 years, 10 months, of age and ending when he was 4 years, 10 months. The five other children ranged in age from 1;5 (years; months) to 4;1 at the time of the first session and from 2;6 to 5;9 at the time of the last; one child was observed for as few as two sessions, one for as many as sixteen. Informal play sessions with a standard set of toys were videotaped roughly every ten to twelve weeks in the child's home. The videotapes were then transcribed and coded according to the system described in detail in Feldman et al. (1978) and Goldin-Meadow (1979); see these reports for information on criteria and reliability for each of the coding categories and also for further details on procedure. Briefly, we reviewed the tapes first to extract those motor acts which appeared to be used symbolically for communicative purposes and then described those acts using the system developed by Stokoe (1960) to describe American Sign Language. We next segmented these gestures into word units and sentence units. Finally, we assigned semantic meanings to each of the sign words and sign sentences, using as guides Bloom's (1970, 1973) method of rich interpretation and Fillmore's (1968a) case descriptions.

In assigning semantic descriptions to sentences, we classified each sentence according to the number of propositions contained within that sentence. Most of David's productions were simple sentences, containing only one proposition. For example,

(1) drum picture-BEAT (*one beats drums*) [David VIIIa 5[5]]

However, David did produce a number of more complex sentences, containing more than one proposition. For example,

(2) knife$_1$-David-knife$_2$-sister (she/mother gave *knife$_1$* to *me/David* and she/mother gave *knife$_2$* to *you/sister*) [David IVa 136]

All the complex sentences containing two propositions that David produced during sessions I through XIII are described in the following sections. I leave aside those complex sentences containing more than two propositions, of which David produced about 150.

Complex sentences

Types of propositions conjoined. My colleagues and I have found previously that the deaf children produced two types of sentences: action and attribute. An action sentence is used to request the execution of an action, or to comment on an action that is being, has been, will be, or can be executed. Sentences (3) and (4) are examples of simple, one-proposition action sentences:

(3) HIT-mother (*you/mother hit* blocks) [David IVa 81]
(4) MARCH-soldier (*he/soldier marches*) [Chris III 117]

An attribute sentence is one that is used to comment on the perceptual characteristics of an object. Sentences (5), (6), and (7) are examples of simple attribute sentences:

(5) elephant trunk picture-LONG (*elephant trunk* is *long*) [Tracy I 141]
(6) black train-black car (*black train* resembles *black car*) [David IVa 40]
(7) picture of soldier-soldier (*picture* resembles *soldier*) [Donald IXa 97]

David conjoined sentences of both types in all possible combinations: action + action, attribute + attribute, and action + attribute sentences. He began to produce action + action sentences earlier than the others (he produced action + action sentences in session I but did not begin to produce attribute + attribute and action + attribute sentences until session II), and he generally produced more action + action sentences (198) then either attribute + attribute (70) or action + attribute (92) sentences. The other five deaf children showed a comparable production pattern (21 vs. 9 and 8, respectively). Sentences (8), (9), and (10) are examples of complex, two-proposition action + action, attribute + attribute, and action + attribute sentences, respectively:

(8) SIP-cowboy picture-SIP-soldier picture-BEAT (*cowboy* sips *straw* and *soldier beats* drum) [David IXa 105]

(9) BIG-SMALL-BIG-BIG (quarter is *big* and penny is *small*) [David Xb 148]
(10) lobster picture-UGLY-DIVE-lobster picture (*lobster* is *ugly* and *lobster dives* into water) [David VIIIa 177]

Conjoining links between propositions. The two propositions in each of David's conjoined sentences were linked in one of two ways: temporally or atemporally. Temporal sentences either described a sequence of events or requested that a sequence of events take place. The conjunction in English most appropriate for these sentences is *and then*; or if the child is suggesting a causal link between the two events, *so that* or *in order to*. Sentences (11), (12), and (13) are examples of temporally linked two-proposition sentences:

(11) TAKE OUT-glasses-DON (you/Heidi *take out glasses* and then I/David will *don glasses*) [David VIa 151]
(12) HIGH-FALL-[wait][6] (tower was *high* and then tower *fell* to ground) [David VIa 177]
(13) GO DOWN-EAT[7] (I/David *ate* cookie and then cookie *went down* to stomach) [David Ib 28]

Note that sentence (13) is a causativelike construction in which the actor acts on a patient which itself then acts (see Bowerman, Chapter 11).

The second type of link was atemporal; that is, it described events not ordered in time. Atemporally linked sentences fell into three categories, the first of which is *coordinate* linkage, that is, sentences that might be linked by *and* in English. To a certain extent, this is a classification by default: If the sentence did not describe a situation in which events were temporally ordered and did not have any of the defining characteristics of the other two categories of atemporal sentences (discussed next), it was classified as an *and* sentence. For example, David described the fact that two Santa toys were strumming two guitars with the following sentence:

(14) guitar$_1$-STRUM-guitar$_2$-STRUM (Santa$_1$ *strums guitar$_1$* and Santa$_2$ *strums guitar$_2$*) [David VIIIb 4]

The second atemporal type again is coordinately linked, but with one of the two propositions (or one element of one proposition) *contrasted*: such sentences might be linked by *but* or *but not* in English. A sentence was coded as a *but* sentence if the child described or requested a situation in which both propositions might have been expected to occur, but in which only one proposition actually did occur; for example, David produced the sentence "pear-banana [+ss]-ROLL" in a situation in which either the pear or the banana could be expected to roll toward his leg. David wanted the pear but not the banana to roll toward him. The [+ss] in this sentence indicates that a negating side-to-side headshake accompanied the sentence, and we therefore glossed the sentence as "*pear* should *roll* to my leg, but *banana* should not *roll* to my leg." In general, *but* sentences contained either a side-to-side headshake or a two-handed flip out to the sides, both actions conveying negation of some aspect of the sentence.

The third category is *subordinate* linkage, where an element in one proposition is restricted or qualified by the second proposition; sentences in this category are analogous to relativized sentences in English that might be conjoined by *which, who, where,* or a similar word. A sentence was considered subordinately linked if one of the propositions described in the sentence was primary in the situation; for example, David described a picture of a bird pedaling a bicycle with the sentence "bicycle picture-PEDAL-bird picture-WING," and because the primary action in the picture was pedaling, we glossed this sentence as "*bird* who *wings pedals bicycle*." As a second example of subordinate links, David produced:

(15) MOVE-palm-EAT (you/Heidi *move* to my *palm* grape which one *eats*) [David VIb 34]

to request Heidi to give him a toy grape. In this instance, the giving proposition appeared to be primary because David wanted the giving, but not the eating, to occur in the situation (David was not about to eat the toy grape); the eating act appeared to be signed in order to elaborate on the edibility of grapes in general. In contrast, when David produced sentence (16) to request a hammer so that he could swing it, the giving act did not appear to be primary but was rather one part of a sequence of two actions, both of which were to occur in the situation. Sentence (16):

(16) GIVE-SWING (You/Mother *give* hammer to me/David and then I will *swing* it) [David IVa 82]

is therefore *not* considered to have a subordinate link. Thus a sentence is classified as subordinate if only one of the propositions conveyed in the sentence is the focus of the situation, with the other proposition used to elaborate on an element of the first.

In general, David produced more atemporal sentences (265) than temporal sentences (95), as did the five other children (29 vs. 9). Within the class of atemporal sentences, David produced *and* sentences most often (157), *which* sentences next most often (65), and *but* sentences least often (43); the same pattern is seen in the other five deaf children (12, 12, and 1, respectively). David began producing both temporal and atemporal sentences during session I. However, onset times varied within the class of atemporal sentences: He began producing *and* sentences during session I and *but* and *which* sentences only during session IV.

Shared elements across propositions. In English, when two propositions are conjoined, there is often at least one element of each of the propositions that is redundant or "shared" in both. For example, in the sentence "Mary cut the apples and John ate the apples," *apples* is shared by both propositions. (The second *apples* could of course be replaced by *them*; this overtly marks the property "shared" in surface structure.)

David's complex sentences also had this property of sharedness. Most of his sentences had one shared element (159); however, he did produce sentences with two shared elements (50) or three shared elements (6), as well as some with no shared elements (52).[8] The five other deaf children showed a similar pattern: Most of their sentences had one shared element (19), some had two (6), some none (4); they produced no sentences with three shared elements. Examples (17), (18), (19), and (20) are sentences with no, one, two, and three shared elements, respectively:

(17) key-OPEN-key-PUSH DOWN (you/Heidi *push down key* and then door will *open*) [David VIIa 6]
(18) CLIMB-SLEEP-horse picture (*horse climbed* house and then *horse slept*) [David Va 212]
(19) Lisa [+ss]-EAT-David-EAT [+nod]-David (*you/Lisa* will not *eat* lunch but *I/David* will *eat* lunch) [David Vb 73]
(20) [ss]-toy$_1$-village-toy$_2$-village (No. You/Heidi put *toy*$_1$ in *village* and you/Heidi put *toy*$_2$ in *village*) [David VIIa 51]

An element can be shared across two propositions in one of several ways. It can play the same role in both propositions, as in example (18), in which the horse is the actor of both the climbing and the sleeping propositions. An element can also switch roles, as in the following example:

(21) PUSH-truck picture-CIRCLE-truck picture (I/David *push truck* and then *truck circles*) [David Va 26]

The truck is the patient of the push proposition but the actor of the circle proposition. These two types of element sharing, role-repeated and role-switched, can obviously occur only in action + action sentences, because the shared element either switches from one action role to another action role or maintains the same action role in both propositions. In contrast, action + attribute sentences present a third type of sharing, role-described, in which an element playing a semantic role in the action proposition is described in the second attribute proposition, as in examples (22) and (23):

(22) ROUND-penny-me (you/Heidi give *me* the *penny* which is *round*) [David IXb 21]

Table 2.1 *Actors and patients in sentences with one shared element*

	Shared element	
	Actor	Patient
Then sentences	21	11
And/but sentences	22	12
Which sentences	13	37
Total	56	60

(23) LAUGH-BEARDED (Santa *laughs* and Santa is *bearded*) [David VIIIb 6]

In example (22), the penny, which is the patient of one proposition, is described, or modified, by the second proposition. In example (23), Santa is the actor of the first proposition and is described by the second proposition.

David produced more role-repeated sentences than any other type: 112 role-repeated sentences, 20 role-switched sentences, 73 role-described sentences, and 10 sentences with both role repetition and role switching. Comparable numbers for the other five children were 7, 6, 8, and 4, respectively.

Conjoining links and shared elements. Actors and patients, as shared elements, tended to appear in sentences with different conjoining links. The actor was the common element in sentences with one shared element equally as often (56 sentences) as was the patient (60 sentences). However, the actor tended to be the shared element in sentences conjoined by temporal *then* links (e.g., "the HORSE climbed the house and then slept") and in sentences conjoined by the coordinate *and/but* links (e.g., "SANTA laughs and is bearded"), whereas the patient tended to be the shared element in sentences conjoined by subordinate *which* links (e.g., "you/Heidi give me the PENNY which is round") (see Table 2.1). There is slight corroboration of this pattern from the other five children: The actor was a common element only twice, both times in *and/but* sentences; the patient appeared as a common element nine times, but only in *which* sentences. In sum, David produced two propositions about an actor as often as about a patient. However, the two propositions were structured differently around each case: For the actor, the two propositions tended to be coordinately or sequentially conjoined; for the patient, one proposition was embedded within the other.

Underlying structure in complex action sentences

Production probability as a surface measure of underlying structure. In our earlier descriptions of the six deaf children's simple action sentences, my colleagues and I found at least one surface measure, production probability, to reflect the underlying structures of these sentences. Our argument for the relationship between production probability and underlying structure proceeds as follows. We note that a given element, for example, the actor, does not have a constant production probability (the likelihood that an element will be signed when it can be). Rather, we find that, within sentences of the same length, actors who perform (e.g., dancers) are more likely to be signed than actors who alter an object's state (e.g., eaters) and are more likely to be signed than actors who change their own locations (e.g., goers). Moreover, eaters and goers are more likely to be signed than actors who change an object's location (e.g., givers). To explain this variation in surface structure, we have suggested that different structures underlie these different types of sentences; specifically, that two-element (one relational role + predicate) structures underlie sentences about dancing (actor-act), whereas three-element structures underlie sentences about eating (actor-act-patient) and going (actor-act-recipient), and four-element structures underlie sentences about giving (actor-act-patient-recipient).[9] Given the two-sign sentence-length limitation of children in this period, a dancer actor in a two-element underlying structure would be more likely to be signed than would an eater or a goer actor in a three-element underlying structure, simply because the "competition" for one of the two surface slots is increased in a sentence with three elements in underlying structure. By this same hypothesis, a giver actor in a four-element underlying structure would be even less likely to be signed, because competition for the limited number of surface slots is still further increased (i.e., four elements compete in underlying structure). We are, in essence, granting that elements which do not appear in the surface forms of the deaf child's sentences can influence those which do. To sum up the situation for simple sentences, the surface pattern of production probability of the actor (as well as of the patient) appears to reflect the two-, three-, and four-element underlying structures of the deaf child's system: Production probability systematically decreases as the number of elements in underlying structure increases.[10]

Underlying structure in complex sentences: two plausible representations. In considering the deaf child's complex sentences, I will again look to the measure of production probability as a surface indicator of underlying structure. As a first step, I consider some plausible underlying structures for complex sentences. A complex sentence is the conjunction of two propositions. The underlying structure of such a sentence presumably reflects this conjunction. For example, a sentence conjoining one proposition about a soldier beating a drum and a second about a cowboy sipping a straw ought to have an underlying structure of six elements: two actors (soldier and cowboy), two acts (beat and sip), and two patients (drum and straw).

This straightforward heuristic for calculating underlying structure in a complex sentence breaks down, however, when we consider complex sentences with shared elements. For example, consider the conjunction of two requests to Heidi: "You/Heidi open the jar and then you/Heidi blow the wand." In this example, as in the preceding one, there are two actor roles; here, however, one actor (Heidi) is assuming both of these roles. We arrive then at two equally plausible representations of the underlying structure of a complex sentence with shared elements: (1) We could assign the shared element two slots in underlying structure, so that the sentence would have a six-element underlying structure (as in the soldier and cowboy example), or (2) we could assign the shared element only one slot in underlying structure; under this scheme, the sentence would have a five-element underlying structure: One shared actor (Heidi), two acts (open and blow), and two patients (jar and wand).

In terms of the linguistic descriptions proposed to account for conjunction in spoken languages, note that assigning two slots to Heidi in underlying structure is comparable to generating the sentence by sentence conjunction; that is, two complete sentences are generated in underlying structure, and the duplicated element is deleted in a later transformation, "Heidi opens the jar and ~~Heidi~~ blows the wand." In contrast, assigning one slot to Heidi is comparable to allowing phrasal conjunction to occur in underlying structure. Phrasal conjunction, as its name suggests, is a coordination of noun phrases, verb phrases, or other nonsentential constituents. When it occurs in underlying structure it allows the conjunction of nonsentential units at an underlying level; consequently, it differs from sentence conjunction, which permits only conjunction of full sentences at this level (see S. Dik, 1968; Dougherty, 1970, 1971; L. Gleitman, 1965; Lakoff & Peters, 1969, for discussions of sentence and phrasal conjunction). Phrasal conjunction in the underlying structure of the example just given would have the two verb phrases (open jar and blow wand) conjoined in underlying structure, so as to create "Heidi opens the jar and blows the wand" at the underlying level. This representation contains no duplicated elements (i.e., Heidi appears only once), and the need for later deletion is therefore alleviated.

In order to determine which of these two hypotheses better describes the representation of underlying structure in the deaf child's complex sentences, we turn again to our surface measure, production probability. As in the deaf child's simple sentences, we expect production probability

to decrease systematically as the number of elements in underlying structure increases.

Assigning two slots to shared elements in underlying structure. We first consider the hypothesis that shared elements should be assigned two slots in underlying structure. We calculate production probability, in this instance for the actor, by initially classifying each sentence according to its hypothetical underlying structure. For example, "OPEN-BLOW-wand," glossed as "you/Heidi open the jar and you/Heidi blow the wand," under the two-slot hypothesis has an underlying structure of six elements as already described. We next classify the sentence according to the number of elements explicitly signed in the sentence; this example has three signed elements: OPEN, BLOW, and wand. We then determine the number of times an actor could have been signed (twice in this example) and the number of times the actor actually was signed (none in this example). Actor production probability is calculated for classes of sentences (those having the same number of hypothesized elements in underlying structure and the same number of explicit elements in surface structure; the example being considered is in a class having six hypothesized elements in underlying structure, three explicit elements in surface structure). This probability is derived by dividing the number of times the actor is actually signed by the number of times the actor could be signed in the sentences of a particular class.

Figure 2.1 presents actor production probability for David's complex action sentences, classified according to underlying structure and number of explicit elements. If we assume that production probability reflects underlying structure in complex sentences as it did in simple sentences, and if the two-slot hypothesis is correct, then actor production probability should systematically *decrease* as the number of elements hypothesized in underlying structure *increases*. In addition, as was the situation for simple sentences, actor production probability should increase across the board as the number of explicitly signed elements in the complex sentence increases, but the same pattern with respect to underlying structure should be maintained.

The data in Figure 2.1 do not support these expectations. Actor production probability necessarily increases as the number of explicitly signed elements increases from two to three to four. However, there is no evidence of a systematically decreasing production probability pattern with increasing underlying structures. Thus the hypothesis that assigns two slots to shared elements in the underlying structure of the deaf child's complex sentences is not supported by the data.

Assigning one slot to shared elements in underlying structure. We turn next to our second hypothesis, that shared elements should be assigned

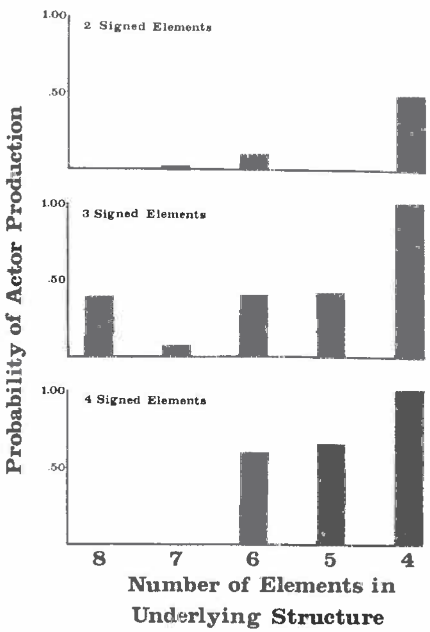

Figure 2.1. Actor production probability in David's complex action sentences as a function of underlying structure assigning two slots to shared elements. Probabilities are based on the total number of actors possible: For 2-signed-element sentences, the number of actors possible in sentences with 8 hypothetical elements was 4; with 7 such elements it was 34; with 6 it was 32; with 5 it was 28; and with 4 it was 8. For 3-signed-element sentences, the numbers of actors possible were 10, 12, 56, 23, and 8, respectively; for 4-signed-element sentences, they were 4, 2, 54, 6, and 4.

only one slot in underlying structure. Actor production probability can be calculated as before, except that now the hypothetical underlying structures are determined by the one-slot hypothesis. For example, the sentence "OPEN-BLOW-wand" would now have a hypothesized underlying structure of five elements: one shared actor, two acts, and two patients (but still would have three explicitly signed elements in surface structure). The number of times an actor could have been signed would now be one (but the number of times the actor actually was signed would again be none).[11]

Figure 2.2 presents actor production probabilities for the data described in Figure 2.1, but this time the sentences are classified according to underlying structures that assign one slot to shared elements. In contrast to our first hypothesis, the one-slot hypothesis results in a pattern that conforms to our predictions: Actor production probability tends to *decrease* as the estimated number of elements in underlying structure tends

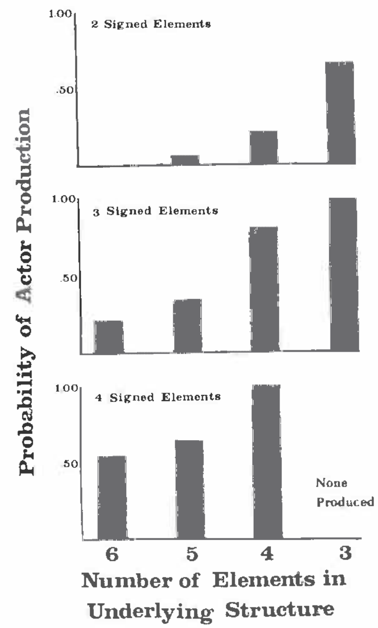

Figure 2.2. Actor production probability in David's complex action sentences as a function of underlying structure assigning one slot to shared elements. Probabilities are based on the total number of actors possible: For 2-signed-element sentences, the number of actors possible in sentences with 6 hypothetical elements was 24; with 5 such elements it was 46; with 4 it was 18; and with 3 it was 6. For 3-signed-element sentences, the numbers of actors possible were 22, 47, 38, and 8, respectively; for 4-signed-element sentences, they were 13, 11, 12, and 0.

to *increase* from three to four to five to six; moreover, this same pattern appears in David's longer sentences with three and four explicitly signed elements, along with the expected across-the-board increase in actor production probability. Thus the generalization that emerged from our studies of the deaf children's simple action sentences (that production probability systematically decreases as underlying structure increases) continues to hold true for complex sentences if one slot is assigned to shared elements in the underlying structures of these sentences.[12]

Patient production probability as a surface measure of underlying structure. A second surface measure, patient production probability, when observed in the six deaf children's simple sentences, was also found to reflect underlying structure. In David's complex sentences, we again find that decreasing patient production probability systematically reflects an increase in underlying structure if underlying structure is formulated by assigning one slot to shared elements. Figure 2.3 presents patient pro-

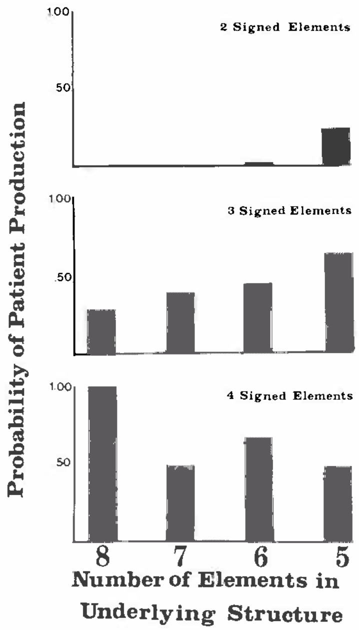

Figure 2.3. Patient production probability in David's complex action sentences as a function of underlying structure assigning two slots to shared elements. Probabilities are based on the total number of patients possible: For 2-signed element-sentences, the number of patients possible in sentences with 8 hypothetical elements was 4; with 7 such elements it was 32; with 6 it was 33; and with 5 it was 8. For 3-signed-element sentences, the numbers of patients possible were 10, 11, 37, and 7, respectively; for 4-signed-element sentences, they were 4, 2, 34, and 2.

duction probabilities for David's two-proposition action sentences classified according to an underlying structure that assigns two slots to shared elements. Figure 2.4 presents the patient production probabilities for the same data classified according to an underlying structure that assigns one slot to shared elements. Although the case is not as strong as for the actor data, postulating an underlying structure with one slot for shared elements better accounts for the patient data (i.e., better upholds the generalizations that production probability decreases systematically as underlying structure increases) than does postulating an underlying structure with two slots for shared elements, particularly for sentences with four explicitly signed elements.

The other five children. When comparable data for the five other deaf children are summed (although the sample is still not large), the hypothesis assigning one slot to shared elements in underlying structure is again

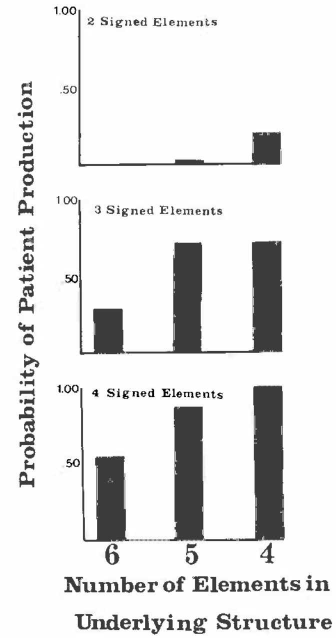

Figure 2.4. Patient production probability in David's complex action sentences as a function of underlying structure assigning one slot to shared elements. Probabilities are based on the total number of patients possible: For 2-signed-element sentences, the number of patients possible in sentences with 6 hypothetical elements was 15; with 5 such elements it was 31; and with 4 it was 9. For 3-signed-element sentences, the numbers of patients possible were 10, 33, and 22, respectively; for 4-signed-element sentences, they were 9, 8, and 6.

supported. If underlying structure is formulated by assigning one slot to shared elements, actor production probability is found to decrease systematically as underlying structure increases from four to six elements (.57 [4/7], .04 [1/25], .00 [0/6] for sentences with two signed elements and .67 [2/3], .50 [5/10], .00 [0/5] for sentences with three signed elements). However, if underlying structure is formulated by assigning two slots to shared elements, this systematic decrease in actor production probability is not found to co-occur consistently with an increase in underlying structure from five to eight elements (.00 [0/4], .21 [5/24], .00 [0/14], .00 [0/2] for sentences with two signed elements and .42 [2.5/6], .38 [3/8], .00 [0/4], .00 [0/4] for sentences with three signed elements). Similar results are found for patient production probability. If underlying structure is formulated by assigning one slot to shared elements, patient production probability tends to decrease systematically as underlying structure increases from four to six elements (.50 [1/2], .56 [5/9], .33 [2/6] for sentences with three signed elements). If underlying structure is formulated by assigning two slots to shared elements, patient production probability does not decrease systematically as underlying structure increases from five to eight elements (.17 [.5/3], .50 [3.5/7], .50 [2/4], .25 [1/4] for sentences with three signed elements).

The units of conjunction. The two-slot hypothesis, which our data do not support, maintains that the underlying structure of every complex sentence contains the conjunction of two full propositions. In contrast, the one-slot hypothesis, which appears to account more satisfactorily for the deaf child's data, allows for the conjunction of parts of propositions as well as full propositions in underlying structure. David did produce a number of sentences conjoining propositions with no shared elements (e.g., "SIP-cowboy-SIP-soldier-BEAT," glossed as "the soldier beats the drum and the cowboy sips the straw"). Sentences of this type must, of course, have underlying structures that conjoin two full propositions. However, David also produced sentences with underlying structures conjoining smaller units, such as two actors ("Heidi-kitchen-David," glossed as "you/Heidi and I/David will go to the kitchen"), two patients ("toy$_1$-village-toy$_2$-village," glossed as "you/Heidi put toy$_1$ and toy$_2$ in the village") and two acts ("[ss]-SWING-CIRCLE AROUND," glossed as "Pinnochio circles around but does not swing"; or "Heidi-STOP-CAPTURE," glossed as "you/Heidi stop and capture the bus"). He also, at times, produced sentences with underlying structure conjoining pairs of elements. For example, he conjoined two acts and patients ("cowboy-RIDE-LASSO," glossed as "the cowboy rides the horse and lassos the steer"), two actors and acts ("TAKE OUT-glasses-DON," glossed as "you/Heidi take out and then I/David will don the glasses"), and two patients and recipients ("knife$_1$-David-knife$_2$-sister," glossed as "she/mother gave knife$_1$ to me/David and knife$_2$ to you/sister").[13] In sum, the production probability data described here suggest that David's system not only allows propositions to be recursive units (that is, units from which we can derive, by the rules of the system, a string which again contains that unit: units that can be derived from themselves) but also allows smaller units, single elements (such as actors) and pairs of elements (such as acts and patients), to be recursive.

Summary

Our results suggest that a deaf child exposed only to a degraded linguistic input can develop a communication system that has the property of recursion, the ability to conjoin two propositions within the boundaries of one sentence. We have found the following properties of recursion to characterize David's communication system.

Conjoining links. Initially, David conjoined propositions that were sequentially linked (*then* sentences) as well as propositions that were atemporally and coordinately linked (*and* sentences). He then began to conjoin propositions that were coordinately but contrastively linked (*but* sentences), as well as propositions that were subordinately linked (*which* sentences).

Shared elements. David's complex sentences contained two propositions that often shared one, and sometimes more than one, element (i.e., sentences in which one element played a role in both propositions). David tended to produce more sentences in which the shared element played the *same* action role in both propositions than sentences in which the shared element *switched* action roles across propositions. Furthermore, in David's sentences, actors tended to be the shared element in temporal *then* sentences and in atemporal coordinate *and/but* sentences; in contrast, patients were shared most often in atemporal, subordinate *which* sentences.

Underlying structure. David's two-proposition sentences appeared to have an underlying structure that took into account shared elements. That is, an element playing two roles, one in each proposition, was assigned only one slot in underlying structure.

In sum, there appears to be structure in the complex sentences produced by a child with degraded input.

2.3. Comparison to child language developed with normal linguistic input

I have shown that a child with a degraded linguistic input can develop certain properties of recursion in his communication system. I have not yet shown, however, that these particular recursive properties are characteristic of human languages in general. After all, the deaf child's system, although structured, might have very little to do with human language as we know it. In order to assert that recursion as it develops in the deaf child's system is a resilient property of human language, I must show that these particular recursive properties are found not only in the deaf child's system but also in language developed under normal learning conditions. Because my subjects are children and cannot be expected to have developed an adult language, I compare recursion in the deaf child's system to recursion in the language of a child of similar age with normal linguistic input.

Onset. The onset of recursion in the spontaneous utterances of hearing children learning Russian has been set between ages 2;4 and 2;6 (Gvozdev, reported in El'konin, 1973). Brown (1973), observing three children learning English, found two-proposition sentences to appear somewhere between 25 months (Adam) and 42 months (Sarah). When we first observed David at age 2;10, he was already producing a few complex sentences; thus, in terms of onset of conjoined propositions, David's time scale appears to be comparable to that of the hearing child.

Conjoining links. In general, children learning spoken language tend to produce *and* and *then* sentences early in development, as did the deaf child in our study (Bloom, Lahey, Hood, Lifter, & Fiess, 1980; Brown, 1973; E. Clark, 1973c; El'konin, 1973; Menyuk, 1971; W. Miller, 1973). For some speaking children, *but* is a later acquisition (Brown, 1973, p. 30), and for some *which* is acquired still later (El'konin, 1973; C. Smith, 1970).[14] This is, in broad outline, the pattern observed in David. Apparently our deaf child's acquisition pattern of conjoining links is found in some hearing children as well.

Shared elements. Sheldon (1974) has found that hearing children aged 3 to 5 understand English sentences with relative clauses more easily if the shared element is playing the same role in both clauses (e.g., "The dog stands on the *horse* that the giraffe jumps over") than if the shared element switches from one action role to another (e.g., "The pig bumps into the *horse* that jumps over the giraffe"). Goldin and Karmiloff (1970) found a similar result with English-speaking children living in Geneva. Moreover, Goldin (1971) has shown the same preference for role-repeated sharing over role-switched sharing in young children presented with active and passive clauses conjoined by *and*, for example, "The *bear* was licked by the monkey and the *bear* was pushed by the mouse" (role-repeated) as opposed to "The *bear* licked the monkey and the *bear* was pushed by the mouse" (role-switched). I found here that David produced more sentences with role-repeated shared elements. Thus the pattern that we find in David's spontaneous productions is also found in the young hearing child's comprehension of English.

David tended to produce shared actors and shared patients in different types of complex sentences. Specifically, David tended to embed a second proposition around the patient but not around the actor. Children learning English show the same tendency in their spontaneous production (Limber, 1973; Menyuk, 1969). It has been suggested that a clause embedded around an actor in subject position in English is difficult for young children simply because the clause interrupts the flow of the sentence and separates the subject from its verb (e.g., "The man who saw the cat ran away"). However, the fact that David also produced few sentences with propositions embedded around actors suggests that the order of elements in English is not the sole impediment to actor embedding for the young child (see Limber, 1976, for an explanation based on pragmatic factors).

In contrast to his use of the patient case, David tended to produce the shared actor in *and/but* and *then* sentences. There is some evidence that children learning English also focus more on shared actors than shared patients in coordinately linked clauses. In an elicited imitation study of coordinate conjunction, Lust (1977) presented children, ages 2 to 3, with sentences containing different types and different numbers of shared elements (e.g., actor shared, actor and act shared, or in Lust's terms, subject shared, subject and verb shared). The sentence was either a full sentence with the shared element appearing twice in surface structure, or a deleted sentence with the shared element appearing only once. In general, the children were better at imitating full sentences with no deletions; for example, "*Daddy* played baseball and *Daddy* sang a song" was easier to imitate than "*Mommy* cooked the dinner and ate the crackers." However, when imitating the full sentences, the children did occasionally make deletion errors (e.g., they would delete the second *Daddy* in the sentence just given). Deletion or reduction errors of this type were committed in sentences with shared actors but almost never in sentences with shared patients.[15] Thus, in coordinate sentences, the child appears to notice and occasionally to mark (by deletion) the "sharedness" of the actor; in contrast, the child almost never indicates (by deletion) that he might have noticed the sharedness of the patient.

Underlying structure. At present there are no studies designed to investigate the underlying structure of complex sentences spontaneously produced by speaking children. There is, however, some suggestion in the literature that hearing children both imitate (Lust, 1977; Roeper, 1973; Slobin & Welsh, 1973; Thieman, 1975) and spontaneously produce (Limber, 1973; Menyuk, 1969, 1971) sentence conjunction forms earlier than phrase conjunction forms (but see Bloom et al., 1980, whose subjects produced phrasal conjunction forms either at the same time as [three subjects] or before [one subject] sentential forms). That is, as already noted, full forms such as "Daddy played baseball and Daddy sang a song" are produced earlier and imitated with fewer errors than deleted forms such as "Daddy played baseball and sang a song." Slobin (1973) suggests that these facts about complex sentences conform to a universal of child language: "It is easier to understand a complex sentence in which optionally deletable material appears in its full form" (p. 203). Slobin further suggests that this universal, among others, is an outgrowth of one of the operating principles the child brings to bear on the task of organizing and storing language – in this case, the principle that "underlying semantic relations should be marked overtly and clearly" (p. 202).

If this hypothesis is correct, we can infer from the hearing child's preference for the sentential forms over the phrasal forms of sentences having the same meaning that the sentential form is closer to the child's semantic structure than is the phrasal form; that is, that in the hearing child's semantic structure only full propositions are conjoined, so that shared elements must be represented twice. This conclusion appears to be in conflict with my claims about the deaf child's system (that the deaf child's underlying structure is formulated in phrasal, not sentential, form, with shared elements represented only once). The key here is the relation between underlying structure and semantic structure.

2.4. The relation of underlying structure to semantic structure

I have found it necessary to posit two levels of representation in order to describe the deaf child's sign system: a surface level and an underlying level. I have, up until this point, skirted the important question of the relationship between underlying structure and the meaning of the sentence, or what might be called semantic structure. The underlying structures I have posited for the deaf child's simple sentences fit neatly with intuitions about the child's semantic structures for these sentences. There is, in fact, no obvious reason to distinguish underlying structure from semantic structure in the deaf child's simple sentences.

In contrast, there may be good reason to draw such a distinction for the deaf child's complex sentences. For the deaf child's complex sentences, I examined two equally plausible candidates for the underlying representation: (1) structure in which only fully formed propositional units can be conjoined, which thus requires that two slots be assigned to shared elements, and (2) structure in which units smaller than the proposition can be conjoined, which allows one slot to be assigned to shared elements. The second interpretation fits the data better.

It is possible that the underlying structure of the deaf child's complex sentences is isomorphic with their semantic structure. A shared element would then be represented only once in semantic structure, as it is in underlying structure. However, it is equally likely that the underlying structure is an intermediary level of representation between the level of meaning and the level of signs. Under this hypothesis, a shared element would be represented twice in the deaf child's semantic structure. (Note that this description of underlying structure is reminiscent of the description of deep structure in transformational grammar. But it is only reminiscent – there is no claim here that the deaf child's underlying structure has the properties ascribed to deep structure in the adult's grammar.)

One argument in favor of this second possibility is that, when we extrapolate from Slobin's operating principle, shared elements appear to be represented twice in the semantic structure of the hearing child's language. It is not unreasonable to assume that the deaf child's semantic structure is comparable to the hearing child's, and that shared elements are also represented twice in the deaf child's semantic structure. On this assumption, we are led to posit for the deaf child's system an intermediary level of representation (called underlying structure) necessary to generate the surface structure of the child's sentences, in which shared elements are represented only once.

2.5. Resilient and fragile properties of language

We have observed the development of a communication system under degraded learning conditions, and have discovered that certain properties of language can be developed under these less-than-perfect conditions. Specifically, the deaf child can develop a communication system that not only conveys action and attribute propositions, but also conveys relationships among these propositions (e.g., temporal, coordinate, contrastive, and subordinate). Moreover, these semantic notions are expressed through a system with many languagelike properties: (1) lexical items that refer to objects, actions, and attributes; (2) syntactic ordering rules and production probability rules that structure the surface forms of sentences; (3) underlying structures that are systematically related to surface structure; and (4) the property of recursion. None of these properties of language apparently requires a finely tuned linguistic input to develop, and in this sense, all are resilient properties of language.

Further evidence for the resilience of these particular language properties comes from studies of language learning under conditions degraded with respect to time of learning, specifically, the study of Genie's language learning outside the critical period. At this moment in her development, Genie has developed a communication system that conveys both action and attribute propositions, as well as relationships among propositions. Moreover, her system has lexical items, syntactic ordering rules, and the property of recursion (Curtiss, 1977).

In addition, the development of some of these same language properties in normal children has been shown to be relatively unaffected by the normal variations in speech to children. Newport, H. Gleitman, and L. Gleitman (1977) have correlated variation in mother speech to the child at time I with the child's rate of acquisition of certain language properties from time I to time II. They have found that properties such as the number of true verbs in a sentence (in our terminology, the number of characterizing signs in a sentence, a feature that partially determines the number of propositions in a sentence) correlates not at all with variations in mother speech at time I. Thus this property, which roughly corresponds to the concatenation of propositions in the deaf child's system, appears to be relatively insensitive to the small variations in normal linguistic input.

In contrast to these resilient properties of language which, weedlike, appear to grow no matter what the conditions, there are other more fragile properties of language, more like hothouse orchids, which appear to require rather specialized fertilization in order to flourish. Specifically, Genie did not develop properties such as the auxiliary and movement rules in her language, and there is no evidence at the moment for such properties in the deaf child's system. In contrast, the auxiliary is one of the few language properties whose rate of acquisition has been shown by Newport et al. (1977) to be sensitive to variation in mother input. Thus there appear to be certain properties of language (such as the auxiliary) that do not flourish under the degraded learning conditions of either the deaf child or Genie, and that are sensitive to normal variations in linguistic input.

The data from these three studies also suggest that there may be a trade-off between time of learning and the quality of input needed for learning. Newport et al. have shown that the acquisition rate of noun inflections, such as the plural ending, is sensitive to variations in linguistic input and therefore might be taken to be a fragile property of language. Indeed, the deaf children in our study have not yet developed plural endings, and Genie did not spontaneously develop plural markers. However, when given explicit and specific training, Genie did acquire the ability to understand plural endings (Curtiss, 1977). Thus improvements in quality of input might, in certain instances, be able to compensate for difficulties in language learning beyond the critical period.

In sum, my data, in conjunction with other studies on language learning, suggest that the child is predisposed or prepared to abstract a resilient property such as recursion from his linguistic model if one is available or, if a model is not available, to induce recursive properties to describe the world around him. In contrast, the child appears to be less prepared to acquire a fragile property such as the auxiliary structure of English. Without a linguistic model or beyond the critical period he will not develop the auxiliary. Even with a linguistic model, small variations in that model turn out to affect the speed with which the auxiliary is acquired. It therefore appears that different principles of learning are operating in recursion acquisition and in auxiliary acquisition. More generally, I suggest that there may be different principles of learning involved in the acquisition of resilient properties of language and in the acquisition of fragile properties of language. In short, I observe that to learn a resilient property of language, it is best to be prepared – but to learn a fragile property, it is best to prepare the linguistic environment.

Notes

1 Rather than discuss the problem as one of innate vs. learned properties, Mayr has introduced the terms *open* and *closed* genetic programs; a closed program

does not allow appreciable modification during the process of development, whereas an open program does allow for additional input during the life-span of the organism.

2 Genie may, of course, still acquire these properties, because she continues to make linguistic progress; at the very least, however, we can say that these properties are not learned early after the close of the critical period.

3 There is, of course, the possibility that the parents of these deaf children are fashioning a spontaneous gesture system that their children are then imitating; see Goldin-Meadow & Mylander (forthcoming) for comparative data suggesting that this is not the case.

4 The children produced a third type of lexical item that we call *markers*. Markers, such as side-to-side headshakes and nods, are notionally similar to words like *no* and *yes* in English. For the most part, markers are not considered in the analyses presented in this chapter (but see "Complex sentences," in Section 2.2).

5 The following conventions will be used in describing examples:
   1. The example should be read from left to right; the sign that occurs first in the temporal sequence is the first entry on the left.
   2. The referents of deictic signs are in lowercase letters (e.g., drum).
   3. Words in small capitals (e.g., BEATS) are glosses for the referents of characterizing signs.
   4. The sentence in parentheses is an English gloss of the sign sentence. The italicized words stand for those referents which are explicitly signed in the sentence; the remaining words stand for referents that are omitted from the sentence, and that must be inferred from context.
   5. The information in brackets indicates the name of the child who produced the sentence (e.g., David), the session in which he produced the sentence (e.g., VIIIa), and the transcription number of the sentence (e.g., 5).

   Note that any sentence which contains two characterizing signs contains two predicates and therefore is classified as a two-proposition sentence. A characterizing sign identifies an object or action by specifically conveying a relational aspect of that object or action; e.g., THROW (curved palm arcs forward in the air) conveys the "throwability" of an object or the act of throwing. Thus, when two characterizing signs are concatenated, two relational aspects are necessarily conveyed, and the sentence is classified as a complex, multiproposition sentence; e.g., THROW-GIVE, meaning perhaps "you *give* me ball which can be *thrown* by someone," or "you *give* me ball and then I will *throw* it," is a two-proposition sentence and is included in the data base for this study.

   In my report of semantic relation classifications in Goldin-Meadow (1979), I described a class of "static" sentences that were not classified as either action or attribute sentences. A sentence was considered to be static if the sentence could potentially be a comment on the static location or possession of an object. I have classified static sentences along with attribute sentences for my discussion here.

6 *Wait* is a marker in David's system.

7 Note that the order of events conveyed in this sentence does not correspond to the order of events in the real world; i.e., cookies are eaten before they

go down. A sentence was classified as temporal if it described events that followed an ordered sequence in the nonlinguistic situation, even if that real-world order was not mirrored in the sentence.

8 Attribute + attribute sentences are excluded from this description primarily because it was not clear whether to consider the *is* predicate in attribute sentences as a potential shared element. For example, in the structure "Ritchie picture-outside-[flip + ss]-upstairs" (*Ritchie* is not *upstairs* but *Ritchie* is *outside*), *Ritchie* is one element shared in both propositions and *is* is potentially a second. If *is* is considered to be a shared element, all attribute + attribute sentences will necessarily have at least one shared element. Most attribute + attribute sentences did, in fact, have one other shared element in addition to the *is*. Sentences in which we had difficulty determining shared elements are also excluded here.

9 Our earlier reports of the data on underlying structure in simple sentences, (Feldman et al., 1978; Goldin-Meadow, 1979) used "case" terminology rather than "element" terminology. Underlying structure was characterized by the number of cases associated with each predicate. It is, however, a simple matter to convert case to element terminology. Because every simple sentence has one and only one predicate, all we need do is add one unit to our original case assignments. Thus one-case underlying structures become two-element underlying structures, two-case become three-element structures, and three-case become four-element structures.

10 A similar pattern of surface-structure variation is found in the simple sentences of hearing children (see Bloom, Miller, & Hood, 1975) and can also be explained by reference to these underlying structures (Goldin-Meadow, 1979).

11 Repetition was necessarily counted differently for the two hypotheses. Consider the sentence "GO UP-SLEEP-horse," glossed as "the horse goes up to the roof and then the horse sleeps." According to the two-slot hypothesis, the number of actors to be signed is two and the number of actors actually signed is one. For the one-slot hypothesis, the number of actors to be signed is one, the number signed is also one. Now consider what would happen if the horse sign were repeated. For the two-slot hypothesis, the number of actors to be signed would again be two, but the number signed would also be two. In contrast, repetition would not change the calculations for the one-slot hypothesis: The number to be signed and the number signed would remain one. As a general comment on repetition in the deaf child's system, it should be noted that repetition does not appear to distinguish shared elements from unshared elements (those which assume only one role in the two propositions): 12 percent (23/196) of shared elements are repeated, as are 9 percent (55/588) of unshared elements. Thus repetition does not appear to serve as a marking device for shared elements in the deaf child's system.

12 It should be noted that no linguistic description assigns role-switched shared elements (i.e., shared elements that play two different roles in the two propositions of a complex sentence, e.g., patient in one proposition switching to actor in the second) one slot in underlying structure. All generate two full sentences in underlying structure, transform one of the sentences so that the shared element occupies the same position in both sentences, and then delete one of the two role-switched shared elements in a later transformation. The question of how role-switched shared elements are treated in the deaf child's system is an interesting one, one that bears directly on issues of constituent structure. However, the small number of sentences with role-switched shared elements produced by the deaf children so far does not yet permit us to address this issue.

13 There is disagreement in the literature on which nonsentential units can be conjoined in underlying structure by phrasal conjunction rules. For example, Lakoff and Peters's (1969) rules allow only for the conjunction of noun phrases in underlying structure (comparable to David's conjoining two actors). Dougherty's (1970, 1971) rules allow for conjunction of verb phrases as well (comparable to David's conjoining two acts and patients), but do not permit conjunction across constituent boundaries; e.g., they permit neither the conjunction of noun phrase + verb units (two actors and acts) nor the conjunction of verbs alone (two acts). In contrast, S. Dik's (1968) rules permit conjunction across constituent boundaries on the assertion that sentences like "She greased and I floured the pan" are perfectly grammatical, an intuition not shared by N. Chomsky (1957) or L. Gleitman (1965), in early treatments.

14 But see Brown (1973), who suggest that English-learning children will embed one relation in another (e.g., by means of *which*) before they begin to produce the coordinate conjunctions *and*, *but*, and *then*.

15 Lust argues that actors, or subjects, to use her term, are more likely to be deleted simply because deletion of a shared actor in subject position always involves "forward" deletion (e.g., deletion of *John* in the *second* clause in "John sang and ~~John~~ danced"). In contrast, deletion of a patient in object position involves "backward" deletion (e.g., deletion of *potatoes* in the *first* clause in "John cut ~~the potatoes~~ and Mary ate the potatoes"). The fact that David favors shared actors over shared patients in coordinate sentences suggests that, in addition to "forward" and "backward" deletion, there may be other factors *not* based on the order of elements in English that contribute to Lust's results.