UNDERLYING STRUCTURE IN SIMPLE AND COMPLEX PHRASES OF A COMMUNICATION SYSTEM DEVELOPED WITHOUT A LANGUAGE MODEL

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The impact of the linguistic environment on a child's acquisition of language is most obviously seen in cross-cultural patterns: french children learn French, german German, japanese Japanese and so on. Moreover, when exposed to conventional sign languages (e.g., American Sign Language or Signed English), deaf and hearing children can learn these conventional sign languages. Thus, from a casual glance around the globe, one concludes that a linguistic model, if present, is important at least on a gross level in shaping the language acquired by a child. This global glance, however, does not allow one to conclude that a language model _must_ be present for language development to occur. What if a child is exposed to neither French, nor German, nor Japanese, nor American Sign Language? Would such a child develop a communication system, albeit a non-conventional one, despite that child's lack of linguistic input?

Over the past several years, I have studied just such a child, in fact, six such children, all lacking conventional language models but experiencing normal home environments in all other respects. My subjects are deaf children whose severe hearing losses have prevented them from acquiring an oral language naturally, and who have not been exposed to a conventional sign language (their hearing parents have focused instead on oral training, e.g., training to use their hearing, to lip-read, and to produce sounds through kinaesthetic feedback). At their current stage, these children are as yet unable to take much advantage of oral cues and therefore, for all intents and purposes, they lack a useable conventional language model, either oral or manual.

Despite this lack of a linguistic input, the children have developed gestural communication systems which we have shown to possess many of the properties of natural languages (Goldin-Meadow and Feldman, 1977; Feldman, Goldin-Meadow and Gleitman, 1978; Goldin-Meadow, 1979). In particular, the children have developed lexical items for people, places, and things (deictic signs, typically pointing gestures which serve to indicate the object referred to), and lexical items for actions and attributes (characterizing signs, iconic gestures whose forms change to accommodate their referents, e.g., a fist jabbed at the mouth refers to the act EAT). Moreover, the children have concatenated these lexical items into simple phrases which convey one relation or proposition (e.g., point at pretzels-EAT-point at Susan, signed when inviting Susan to eat the pretzels), and into complex phrases which convey two or more relations (e.g., point at Lisa+ side to side headshake-EAT-point at David-EAT-point at David+ nod, signed when David but not Lisa was about to eat lunch). Without the benefit of a conventional language model, the deaf children have apparently developed the rudiments of a language-like communication system.

This paper demonstrates that, like natural languages, the deaf child's system can best be described by positing an underlying structure for both simple and complex sign phrases. Underlying structure is proposed therefore to be among the language properties which can be developed under less-than-optimal language learning conditions.

Subjects, Procedure and Coding Categories

Six children, all congentially deaf with no other known cognitive or physical handicaps, were observed and videotaped at play in their homes at intervals of one to three months. None of the children could acquire oral language naturally even with a hearing aid, and all were of hearing parents who knew no conventional sign language.[2] Five of the six children attended oral schools for the deaf in the Philadelphia area; the sixth began school after our observations ended. Sign Language was not taught in any of these oral schools.

The children ranged in age from 1 year, 5 months to 4 years, 1 month at the first interview. Dennis, Chris, and Tracy were studied for two to four months, while David, Donald, and Kathy were followed for two to three years and are still under study. The sessions lasted from one to three hours, depending upon the child's patience, and consisted of informal play with a standard set of toys between the child and mother and/or between the child and experimenter. Videotapes were transcribed according to a coding system described in detail by Feldman et al., 1978, and Goldin-Meadow, 1979. Reliability ranged from 91% to 99% depending upon the coding category.

Simple Phrases

All six children produced simple phrases conveying action relations. Each phrase was classified, on the basis of non-linguistic context, according to the particular type of action relation conveyed. Phrases about transferring an object to a new person or place were labeled transfer (e.g., giving). Phrases about an action on an object, affecting the state of that object either permanently or temporarily (but not altering the location of the object) were labeled transform (e.g., eating, striking). Phrases about an object or person changing its own location were labeled <u>transport</u> (e.g., going). Phrases about an object or person performing an action on itself, affecting its own state but not another's were labeled <u>perform</u> (e.g., dancing, walking).[3] The strategy in establishing the existence of an underlying structure for the deaf child's communication system was first to assign an hypothetical underlying structure to each of these four relation types, and then to determine if any surface measure would vary systematically with these hypothetical underlying structures.

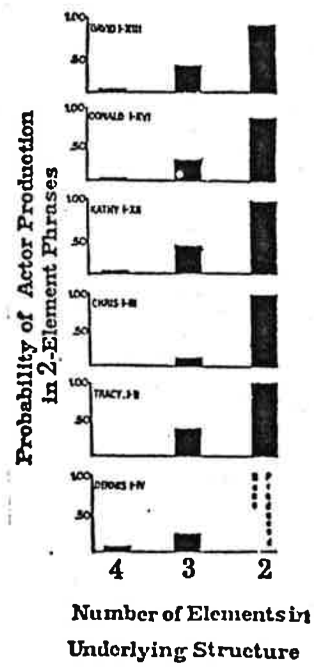
On (adult) intuitive grounds, a transfer relation appears to involve four component elements: the giver (actor), the given (patient), the given-to (recipient), and the giving (act), and therefore was assumed to have a 4-element underlying structure. In contrast, transform and transport relations each intuitively involve only three component elements: the eater (actor), the eaten (patient), and the eating (act) for transform, and the goer (actor), the gone-to (recipient) and the going (act) for transport, giving each a 3-element underlying structure. Finally, perform relations apparently involve only two component elements: the dancer (actor) and the dancing (act), creating a 2-element underlying structure. Note that these divisions into elemental parts are hypotheses about the way we encode action relations. In fact, they are quite reasonable (and very intuitive) hypotheses for adults. However, we wish now to determine whether the child himself uses these simple structures to organize his action relation phrases. We therefore turn to one of the child's own production measures.

The surface measure chosen for investigation is <u>production probability</u>: the probability that an element will be explicitly signed when that element can be signed. This measure is an outgrowth of the apparent length limitation on the deaf child's sign phrases. Just as the hearing child goes through a stage of producing primarily two-word sentences, at a certain period in his development the deaf child primarily produces two-sign phrases. When conveying a transfer relation, for example, the child at the two-sign stage will be able to encode certain aspects of the relation but will be forced to omit other (<u>a priori</u>) equally likely aspects. For instance, when requesting his mother to give a book to his sister, the two-sign child might point at the book and then produce a sign for give, explicitly signing the <u>patient</u> and the <u>act</u>. Note, however, that at the same time he will have omitted a sign for mother, the <u>actor</u>, and for his sister, the <u>recipient</u>. Production probability is taken then as the probability that a particular element (e.g., the actor) will be signed in phrases where, given the hypothesized underlying structure, that element might possibly be signed.

If the hypothesized underlying structures (4-element, 3-element, and 2-element) are correct for the child, we might expect the surface measure (production probability) to vary systematically with these structures. Given the two-sign phrase length restriction, an actor in a 2-element perform relation might be more likely to be signed than would an actor in a 3-element transport or transform relation, simply because the "competition" for one of the two surface slots is increased in a phrase with three elements in underlying structure. By this hypothesis, an actor in a 4-element transfer relation sould be even less likely to be signed since "competition" for the limited number of surface slots is still further increased (i.e., four elements competing in underlying structure). Thus, if we are correct about the existence of these particular underlying structures, actor production probability should be highest in phrases with 2-element underlying structures, less in phrases with 3-element underlying structures, and least of all in phrases with 4-element underlying structures.

Figure 1 presents actor production probabilities in phrases with two signed elements for all six children. As predicted. actor production probability varies systematically with hypothesized underlying structure: highest for 2-element underlying structures, lower for 3-element, and lowest for 4-element.

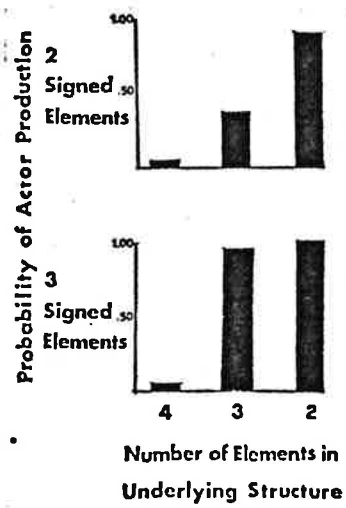
<u>Figure 1</u>. Actor Production Probability in Simple Phrases as a Function of Underlying Structure. Probabilities are based on the total number of two-signed element phrases of each structure type: for David the totals are 4-element = 88, 3-element = 123, 2-element = 17; for Donald 40, 37, 5; for Kathy 16, 12, 3; for Chris 14, 8, 4; for Tracy 2, 15, 6; for Dennis 13, 11, none.



Note that <u>a priori</u>, there is no particular reason to expect actors of differing relations to vary in production probability. For example, it is not easy to conceive of why a dancer should be more likely to be signed than an eater, or an eater more likely to be signed than a giver. Yet these apparent priorities are real for the deaf subjects, holding up across all the children and within each child over developmental time. It is only when we consider a dancer to be a member of a 2-element underlying structure, an eater or goer to be a member of a 3-element underlying structure, and a giver to be a member of a 4-element underlying structure that the observed actor production probabilities become explicable.

Figure 1 presents actor production probabilities for phrases with two signed elements. Occasionally, however, the children did produce longer phrases with three signed elements. What would the underlying structure hypothesis predict for these longer phrases? Presumably "competition" among underlying elements would decrease as more slots become available in surface structure. Thus, actor production probability in three-sign phrases should increase generally compared to two-sign phrases, but it should follow the same probability pattern with respect to the particular underlying structures. Figure 2 presents the data in Figure 1 summed across all six children for phrases with two signed elements, as well as comparable summed data for phrases with three signed elements. As expected, in the three-sign phrases, actor production probability increases across the board, but conforms to the predicted pattern: actor production probability is greater for phrases with 2- and 3-element underlying structures than for phrases with 4-element underlying structures.[4]

Figure 2. Actor Production Proability in Simple Phrases as a Function of Underlying Structure and Number of Signed Elements. Proabilities are based on the total number of two- and three-signed element phrases of each structure type produced by all six children: the totals for two-signed elements phrases are 4-element = 281, 3-element = 391, 2-element = 97; for three-signed element phrases 29, 28, 4.



Production probability for the patient also bears out the underlying structure hypothesis. By definition, patients cannot appear in the intransitive perform and transport phrases. Therefore, the data in Figure 3 are patient production probabilities of all six children for transfer and transform phrases, hypothesized to have 4-element and 3-element underlying structures, respectively. For five of the six children patient production probability was higher in phrases hypothesized to have 3-element underlying structures than in phrases hypothesized to have 4-element underlying structures. Again it should be stressed that _a priori_, there is no reason to expect an eaten-apple to be more or less likely to be signed than a given-apple. It is only when these patients are considered as elements in two different underlying configurations that the observed patient probabilities make sense.

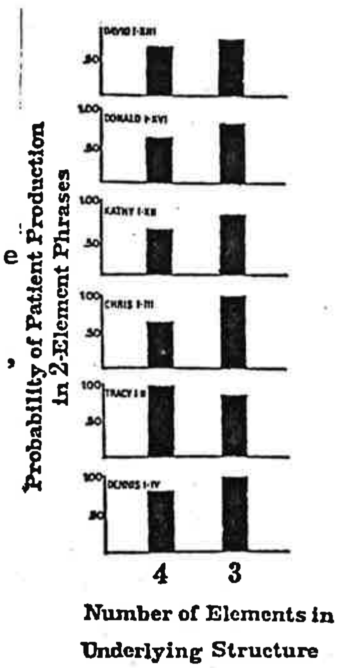


Figure 3. Patient Production Probability in Simple Phrases as a Function of Underlying Structure. Probabilities are based on the total number of two-signed element phrases of each structure type: for David the totals are 4-element = 88, 3-element = 88; for Donald 40, 29; for Kathy 16, 9; for Chris 14, 7; for Tracy 2, 13; for Dennis 13, 10.

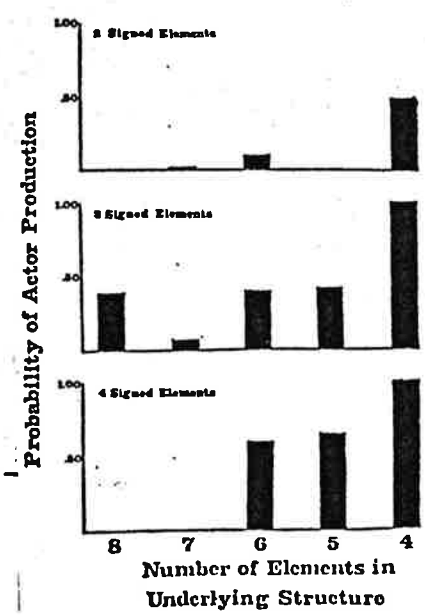
In summary, we have found that production probabilities are not constant across different types of actors and patients in the deaf child's simple phrases. In order to explain this variation in surface structure, we have found it necessary to posit a second descriptive level, which we call underlying structure, as part of the deaf child's communication system.

Complex Phrases.

Complex phrases are defined as phrases conveying two or more relations of any type. Only those complex phrases conveying two action relations were included in the data base for the following analysis. David, over the 13 sessions, produced approximately 500 complex phrases, 200 of which contained two action relations. The other children produced fewer such phrases (summed, approximately 90 complex phrases, including 40 two-action phrases). Consequently, the underlying structure analysis for complex phrases was done on David's data alone.

Given that underlying structure has been found for simple phrases, the most straightforward initial estimate of underlying structure in a complex phrase would be simply to add the underlying structures of the two simple relations which comprise that phrase. For example, in a complex phrase comprised of two 3-element transform phrases (SIP-point at cowboy picture-SIP-point at soldier picture-BEAT, signed about a cowboy sipping a straw and a soldier beating a drum), six elements are potential in underlying structure: 2 actors (cowboy and soldier), 2 acts (sip and beat) and 2 patients (straw and drum). If the child were to conjoin a 3-element transform phrase about eating and a 2-element perform phrase about dancing, the number of elements in underlying structure would be five: 2 actors (the eater and the dancer), 2 actions (eat and dance), and 1 patient (the eaten). By this means, we attempted to establish hypothetical underlying structures for David's complex phrases simply by adding the underlying structures of the two simple relations in each phrase.

As before, we now attempt to justify the postulation of an underlying structure in the deaf child's complex phrases by determining a surface marker of the child's explicit language, and showing that this surface marker varies systematically as predicted by the hypothesized underlying structure. The surface measure chosen is again actor production probability, the probability that the actor element will be signed in phrases where it can be. We might expect again that in phrases with small underlying structures where "competition" for the surface slots is relatively low, actor production probability will be high. When "competition" is increased in phrases with larger underlying structures, actor production probability ought to decrease accordingly. Figure 4 shows the actor production probabilities for all of David's two-relation complex phrases, classified according to underlying structure and according to the number of elements signed in each phrase. Production prob-



<u>Figure 4</u>. Actor Production Probability in Complex Phrases as a Function of Underlying Structure. Probabilities are based on the total number of actors possible in two-, three-, and four-signed element phrases of each structure type: the totals for two-signed element phrases are 8-element =4, 7-element = 34, 6-element = 52, 5-element = 28, 4-element = 8; for three-signed element phrases 10, 12, 56, 23, 8; for four-signed element phrases 4, 2, 54, 6, 4.

ability necessarily increases as the number of signed elements increases from two to three to four. However, the expected pattern, high production probability in phrases with small underlying structures decreasing accordingly as underlying structures become larger, is not borne out particularly well by the data. The underlying structure hypothesized so far for the deaf child's complex phrases does not appear to predict in any reliable way the surface structure variability of the actor element in these complex phrases. We are obliged to rethink the issue.

The reasonable next step is to reconsider our initial estimates of underlying structure in complex phrases. We note that often when a complex phrase is produced, one or more elements is involved in both of the relations in the phrase. For example, in the phrase, GO UP-SLEEP-point at horse picture, signed to comment on the fact that the horse had gone up to the roof and slept, the horse is playing an actor role twice, once as a goer, and once as a sleeper; that is, one element was playing two roles. As yet, our estimates of underlying structure have not taken element-sharing of this type into account: the estimate of underlying structure for this phrase was five, 2 actors (the horse as goer and the horse as sleeper), 2 acts (go up and sleep), and 1 recipient (the roof), with the horse assuming two of those slots.

To investigate underlying structure in complex phrases taking element-sharing into account, the same phrases were reflassified using a new formula for calculating underlying structure. If an element in the phrase plays two roles, we propose that element to be assigned only one slot in underlying structure. Thus, in the above example, the underlying structure for the horse phrase would be four: 1 shared actor (the horse), 2 acts (go up and sleep), and 1 recipient (the roof). Element-sharing can also occur when one element is playing two different roles. For example, in a phrase about David pushing down a bus toy so it would then go forward, the bus was a patient in the first transform relation (PUSHDOWN) as well as an actor in the second transport relation (GO). Thus, the underlying structure for this phrase is five: 1 shared actor/patient (the bus), 1 actor (David), 2 acts (pushdown and go), and 1 recipient (the end of the board).

Figure 5 presents the same actor production probability data as in Figure 4, but this time the phrases are classified according to underlying structure taking element-sharing into account. Again, production probability increases in general as the number of signed elements increases from two to three to four. But now the data show the expected regular decrease in actor production probability with increasing underlying structure; that is, actor production probability is highest for phrases with a 3-element underlying structure and decreases consistently as underlying structure increases from 4- to 5- to 6-elements.

Thus, the hypothesis that the deaf child's complex phrases have underlying structure which takes element-sharing into account, is apparently borne out by the surface marker variability of actor production probability.

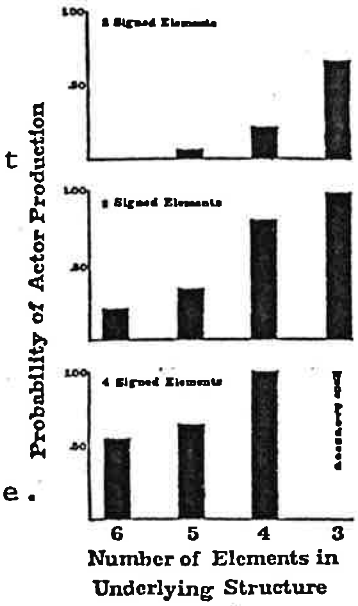


Figure 5. Actor Production Probability in Complex Phrases as a Function of Underlying Structure Taking Element -Sharing into Account. Proabilities are based on the total number of actors possible in two-, three-, and four-signed element phrases of each structure type: the totals for two-signed element phrases are 6-element = 24, 5-element = 46, 4-element = 18, 3-element = 6; for three-signed element phrases 22, 47, 38, 8; for four-signed element phrases 13, 11, 12 none.

When another surface measure, patient production probability, is analyzed in a similar fashion, the underlying structure hypothesis taking element-sharing into account continues to be supported. Figure 6 presents patient production probabilities for David's complex phrases analyzed according to underlying structure <u>without</u> element-sharing.

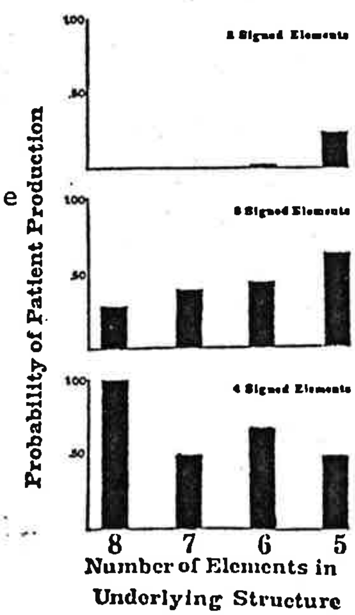
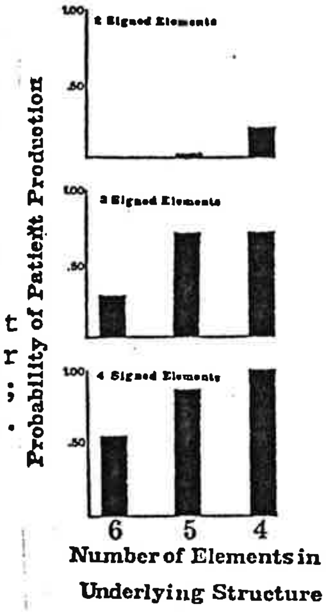


Figure 6. Patient Production Probability in Complex Phrases as a Function of Underlying Structure Without Element-Sharing. Probabilities are based on the total number of patients possible in two-, three-, and four-signed element phrases of each structure type: the totals for two-signed element phrases are 8-element = 4, 7-element = 32, 6-element = 33, 5-element = 8; for three-signed element phrases 10, 11, 37, 7; for four-signed element phrases 4, 2, 34, 2.

Figure 7 presents the same data analyzed according to underlying structure taking element-sharing into account. Although not as strong as for the actor data, postulating an underlying structure with element-sharing (Fig. 7) better accounts for the patient data than does postulating underlying structure without element-sharing (Fig. 6), particularly for phrases containing four signed elements.



<u>Figure 7</u>. Patient Production Probability in Complex Phrases as a Function of Underlying Structure with Element-Sharing. Probabilities are based on the total number of patients in two-, three-, and four-signed element phrases of each structure type: the totals for two-signed element phrases are 6-element = 15, 5-element = 31, 4-element = 9; for three-signed element phrases 10, 33, 22; for four-signed element phrases 9, 8, 6.

In sum, both actor and patient surface measures provide evidence for underlying structure in the simple and complex phrases of the deaf child's communication system. The fact that this system was developed under unique language learning conditions suggests that a young child can develop this underlying structure with little help from the linguistic environment.

The language task for the child born into a culture is to discover the grammar of that culture's language. The difficulty of this task cannot be underestimated. It is not all evident, for example, how the child succeeds in abstracting underlying structure from the surface structure of the incoming linguistic stream. However, we have shown here that even when conventional linguistic data are lacking, the child is predisposed to create a communication system in which language-like properties, including the important property of underlying structure, are evident. Thus, potentially insurmountable tasks such as abstracting underlying structure from surface structure, may be circumvented by the child's own propensity to develop a system with certain properties, in this case, a system with the property of underlying structure.

FOOTNOTES

1. I thank William Meadow, Elissa Newport, and Marilyn Shatz for reading earlier versions of this paper, Ralph Bloom, Robert Fulton, Jeff Harlig, and Miriam Rabban for help in videotape transcription, and my subjects and their families for their cooperation and friendship. This work was supported by National Science Foundation Grant, BNS77-05990 and Biomedical Research Support Grant, PHS 5 S07 RR-07029-13.

2. There is, of course, the possibility that the parents of these deaf children might be fashioning a spontaneous gesture system which their children could then imitate; see Goldin-Meadow (1979) and Feldman et al. (1978) for preliminary data suggesting that this is not the case.

3. The third sign in a three-sign phrase conveying a 2-element relation is the place case. The surface form of such a phrase includes the actor, the act, and the place (e.g., elephant picture-DIVE-water picture, a comment on a picture of an elephant diving while in a pool of water.

4. Transport and perform phrases, both about intransitive actions, often had to be distinguished on the basis of sign form. For example, if a child is commenting on a walking duck and he moves his two flat palms up and down in place, the phrase is considered to be about a change of state and therefore perform. If, however, he moves his two palms (or simply moves one palm) forward, the phrase is considered to be about a change of location and therefore transport.

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