Gestural Communication in Deaf Children: Noneffect of Parental Input on Language Development

Abstract. *Young deaf children who were unable to acquire oral language naturally and who had not been exposed to a conventional manual language were found to use spontaneously a gesture system that has some of the structural characteristics of early child language. The structural aspects of this gesture system appeared to be neither modeled for the child by the gestures of an adult nor shaped by the responses of an adult. These findings suggest that the child may contribute to structural aspects of the system.*

The deaf children in our study had hearing parents who elected to educate them by the oral method (*1*). We reported earlier (*2*) that, although these children had not been exposed to conventional sign language, they were able to develop a gestural communication system with some of the observed properties of early child language: consistent ordering of elements (the placement of words, or gestures, for certain semantic elements in consistent orders within a sentence) (*3*); differential probabilities of production of elements (the explicit production of words, or gestures, for certain semantic elements in a sentence more often than for other semantic elements) (*4*); and recursion (the concatenation of more than one proposition within a sentence) (*5*). Thus it appeared that they were able to develop a structured and productive communication system without a conventional linguistic model.

It was possible, however, that the children's hearing parents influenced the structure of this gesture system. We investigated two likely parental influences on the child's system: modeling, where the child learns the structure of his or her gestures, either by imitation or induction, from the structure of the parents' gestures; and shaping, where the structure in the child's gestures is reinforced by differential parental responses.

To determine whether the deaf children in our study might merely be imitating an adult's gestures, we videotaped four of the children and their mothers during play sessions. We classified the children's gestures as (i) spontaneous, if they were not preceded by parental gesture or were different from the parent's immediately preceding gestures, or (ii) imitated, if they were exact or partial imitations of the parent's immediately preceding gestures. Imitated gestures were found to be infrequent: 2 percent (1 of 58) of Karen's gestures, 5 percent (7 of 144) of Marvin's, 7 percent (7 of 93) of Abe's, and none (0 of 27) of Mildred's.

We next considered the possibility that the children induced a structure from their parents' gestures. We noted at the outset that gesture, not speech, was the children's primary means of communicating (only 1 to 4 percent of the children's communications contained meaningful speech); the mothers communicated by both gesture and speech (83 to 96 percent of the mothers' communications contained speech). Despite the fact that for a hearing person gesture and speech might form an integrated communication system, we chose to analyze mothers' communications from what we took to be their deaf children's point of view and therefore included only the mothers' gestures in our analyses (*6*).

The gestures of six deaf children and their mothers were transcribed according to a system developed earlier (*2, 7*). Reliability—agreement between two coders in independently noting and segmenting individual gestures and assigning them to semantic categories—ranged from 83 to 100 percent. Two types of denotative signs were coded: deictic signs (pointing gestures which indicated objects) and characterizing signs (gestures whose forms were transparently related to the actions they represented—for example, a closed fist bobbed near the mouth to characterize the act of eating). Deictic and characterizing signs could be concatenated to form simple sign sentences that conveyed one proposition [for example, gestures for "jar twist," indicating that the jar (object acted upon, or "patient" in the linguist's terminology) had been twisted open (act)], or complex sign sentences that conveyed at least two propositions [for example, "jar twist blow," a request that the jar (patient) be twisted open (act_1) and bubbles be blown (act_2)] (*8*). We stress that we use linguistic terms such as sentence loosely and only to suggest that the deaf child's gesture strings share certain elemental properties with early sentences in child language.

We found that for five of the six children in our experiment the probability of producing in a two-sign sentence a sign for an intransitive actor ("boy" in the proposition "boy goes to mother") was comparable to the probability of producing a sign for a patient ("boy" in the proposition "mother hits boy"), and distinct from the probability of producing a sign for a transitive actor ("boy" in the proposition "boy hits mother") (Fig. 1). This same probability pattern was found in only two mothers, one of whom was the mother of Abe, the only child who did not convincingly show the pattern. Thus, the systems of mother and child differed in the probability of certain semantic roles (intransitive actor, patient, or transitive actor) being signed explicitly in two-sign sentences.

Furthermore, each of the six children's simple two-sign sentences could be characterized by at least one reliable construction order: patient-act, such as "grape eat" [David (N = 38) and Dennis (N = 11), $P < 0.01$; Mildred (N = 27), $P < 0.05$; Karen (N = 25), $P < 0.10$; χ^2 tests]; patient-recipient (recipient, the end point of a change of location), such as "cup table" [Marvin (N = 15), $P < 0.01$; David (N = 19), $P < 0.001$; χ^2 tests]; or actor-act, such as "dog jump" [Abe (N = 11), $P = 0.002$; χ^2 test]. In contrast, three mothers used no consistent construction orders, and the other three (mothers of Mildred, Abe,

Table 1. Complex sign sentences produced by six deaf children of hearing parents and their mothers.

Child	Age (months)	Session first observed		Child		Mother	
		Child	Mother	Complex sign sentences (N)	Total sign sentences (%)	Complex sign sentences (N)	Total sign sentences (%)
David	34 to 44	1	1	88*	26	8	12
Marvin	35 to 50	1	6	38†	23	2	6
Karen	37 to 50	1	6	31‡	22	1	4
Dennis	26 to 30	1		4§	11	0	0
Abe	27 to 45	2	5	45‖	25	1	3
Mildred	16 to 44	5	4	11¶	12	2	2

*Chi-squares were performed by comparing each child's complex sign sentences to those of his mother. $\chi^2(1) = 5.62$, $P < 0.02$. †$\chi^2(1) = 3.79$, $P < 0.10$. ‡$\chi^2(1) = 2.87$, $P < 0.10$. §Dennis's mother produced nine sign sentences but none was complex. ‖$\chi^2(1) = 8.06$, $P < 0.01$. ¶$\chi^2(1) = 5.12$, $P < 0.05$.

and Karen) displayed only a reliable patient-recipient construction order ($N = 8$, $P = 0.07$; binomial for each), an order not used by any of their children. Moreover, five children produced sentences following their own reliable construction orders an average of three sessions before their mothers produced any sign sentences in that order. Thus, the deaf children's reliable construction orders were not modeled by their hearing mothers' simple sign sentences.

We also analyzed use of complex sign sentences and found that all six children used complex sign sentences more frequently (*9*) and four used complex sign sentences earlier than did their mothers (Table 1). Taken together the data suggest that the structure of the deaf child's sign sentences was not induced from the mother's gestural model (*10, 11*).

We next considered the possibility that the structure of the deaf child's sign sentences was in some way shaped by differential parental responsiveness to those sentences. Following Brown and Hanlon (*12*), we categorized the responses of the mothers and the experimenter to the sign sentences of four deaf subjects as either sequiturs (relevant and comprehending reactions to the child's sentence) or nonsequiturs (queries, irrelevant responses, misunderstandings, no responses, or responses of doubtful classification). We considered the child's sentence order to be preferred if it conformed to that child's reliable order and nonpreferred if it did not; for example, since Marvin reliably produced sentences with patient-recipient orders, sentences with this order were considered preferred for him, and recipient-patient sentences, nonpreferred. We found that the deaf child's sentences with preferred orders were no more likely to be followed by sequitur responses than were sentences with nonpreferred orders [49 percent (24 of 49) preferred and 47 percent (8 of 17) nonpreferred; $P > 0.50$, Fisher's exact test with children individually tested]. Thus the child's preference for particular sign orders does not appear to be a function of communication pressure from the adult.

To determine whether communication pressure was shaping the deaf child's production-probability pattern we looked at sequiturs that followed sentences with preferred production-probability patterns (two-sign sentences with either an explicit patient, an explicit intransitive actor, or an implicit transitive actor) and sentences with nonpreferred patterns (two-sign sentences with either an explicit transitive actor, an implicit patient, or an implicit intransitive actor). We found that sentences with preferred production-probability patterns were no more likely to receive sequitur responses from the mother or experimenter than were sentences with nonpreferred patterns [46 percent (32 of 69) preferred and 50 percent (9 of 18) nonpreferred; $P > 0.67$, Fisher's exact test with children individually tested].

Finally, to determine whether contingent approval might have shaped the structure of the deaf children's sign sentences, we coded (*12*) the mother's and the experimenter's responses as approvals if they contained smiles or nods or complied with the child's request or query, and as disapprovals if they contained headshakes or frowns or did not comply with the child's request or query (sentences not responded to were not counted). We found that sentences following preferred sign orders were no more likely to be approved by mother or experimenter than were sentences following nonpreferred orders [65 percent (22 of 34) preferred and 67 percent (8 of 12) nonpreferred; $P > 0.42$, Fisher's exact test with children individually tested]. Further, approval of sentences with preferred production-probability patterns was found to be similar to that for sentences with nonpreferred patterns [73 percent (29 of 40) preferred and 83 percent (10 of 12) nonpreferred; $P > 0.25$, Fisher's exact test with children individually tested]. In sum, it appears that neither communication pressure nor contingent approval shaped the deaf children's sign orders or probabilities of sign production.

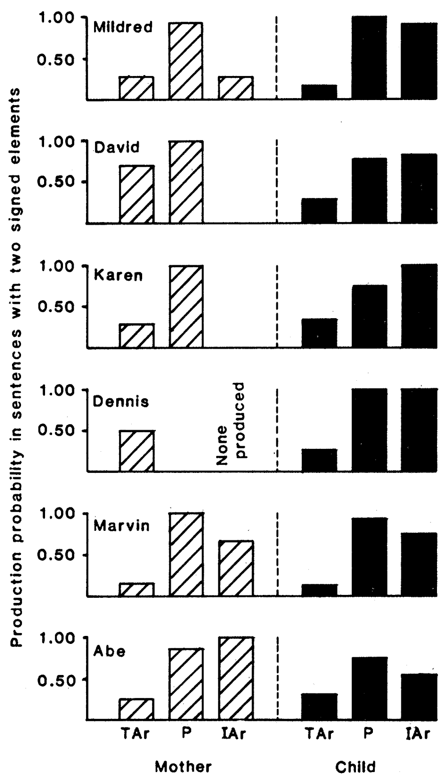

Fig. 1. Production-probability patterns in simple sign sentences of mother and child. Probabilities were calculated only from sign sentences with two explicit semantic elements: Mildred's mother used 14 transitive sentences (the data base for the transitive actor and patient probabilities) and 4 intransitive sentences (the data base for the intransitive actor probability); her child used 22 and 2, respectively. David's mother used 10 transitive sentences and 1 intransitive sentence; her child used 54 and 16, respectively. Karen's mother used 7 transitive sentences and 1 intransitive sentence; her child used 23 and 4, respectively. Dennis's mother used 2 transitive sentences and no intransitive sentences; her child used 10 and 1, respectively. Marvin's mother used 6 transitive sentences and 8 intransitive sentences; her child used 30 and 4, respectively. Abe's mother used 8 transitive sentences and 2 intransitive sentences; her child used 29 and 19, respectively. *TAr*, transitive actor; *P*, patient; *IAr*, intransitive actor.

Our observations indicate that a child in a markedly atypical language learning environment can apparently develop communication with language-like properties without a tutor modeling or shaping the structural aspects of the communication. These results suggest that the child has a strong bias to communicate in language-like ways.

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References and Notes

1. That is, rather than learn a sign language such as American Sign Language or Signed English, the children were taught to read lips and to produce spoken English through kinesthetic cues. At the time of our study, the children (all of whom had severe to profound hearing losses) were producing only a few single words and never combined words into sentences.
2. S. Goldin-Meadow and H. Feldman, *Science* **197**, 401 (1977); H. Feldman, S. Goldin-Meadow, L. R. Gleitman, *Action, Gesture and Symbol*, A. Lock, Ed. (Academic Press, New York, 1978), pp. 349–414; S. Goldin-Meadow, *Studies in Neurolinguistics*, H. Whitaker and H. A. Whitaker, Eds. (Academic Press, New York, 1979), vol. 4, pp. 125–209.
3. D. I. Slobin, in *Studies of Child Language Development*, C. A. Ferguson and D. I. Slobin, Eds. (Holt, Rinehart & Winston, New York, 1973), pp. 175–208.
4. L. Bloom, P. Miller, L. Hood, in *The 1974 Minnesota Symposium on Child Psychology*, A. Pick, Ed. (Univ. of Minnesota Press, Minneapolis, 1975), pp. 3–55.
5. R. Brown, *A First Language* (Harvard Univ. Press, Cambridge, Mass., 1973).
6. Although the children could in principle have been getting speech input through lip reading, in fact they seemed to understand little of the English spoken to them. Indeed, the structure of the children's gesture systems did not reflect the structure of English; in particular, the children's construction orders differed from those found in canonical English sentences, and the children's production-probability pattern was an analog of the structural case-marking pattern of ergative languages and therefore was distinct from the accusative case-marking pattern seen in English (S. Goldin-Meadow and C. Mylander, in preparation).
7. Criteria for sign sentences were the same for mother and child: if the hands did not relax between the production of two signs, these two signs were considered part of one sentence.
8. For examples of complex sentences, see S.

Goldin-Meadow, in *Language Acquisition: The State of the Art*, L. R. Gleitman and E. Wanner, Eds. (Cambridge Univ. Press, New York, 1982), pp. 51–77.
9. Quantitative differences such as these are inconclusive since they suggest only that certain structures are less frequent in mother's gestures than in the child's. However, in order to argue that the child induces consistent structure from the infrequent instances of structure found in his mother's gestures, one must allow that the child is coming to the learning situation with a bias toward making those inductions.
10. Although the camera might have inhibited the mother's gesture production overall, it is unlikely that the camera affected the way in which the mother structured or failed to structure her gestures. The "camera-shy" hypothesis is further weakened by the fact that, for five mothers, the rate of single-sign production was higher for mother than for her child (although each mother's rate of production of the more complex sign sentence form was half that of her child).
11. It is possible that individuals other than parents (such as siblings or the experimenters themselves) influenced the development of the gesture system, but three of the ten deaf children had no siblings, suggesting that interaction with a sibling was not necessary to develop a structured gesture system. Experimenters made every effort not to gesture to the deaf children, and few of the children's gestures were imitations of the experimenter's gestures (2 percent, 1 of 58, overall); the experimenter produced so few gestures on videotape that analysis for structural properties was unnecessary.
12. R. Brown and C. Hanlon, *Cognition and the Development of Language*, J. R. Hayes, Ed. (Wiley, New York, 1970), pp. 11–54.
13. We thank L. Gleitman, J. Huttenlocher, M. McClintock, W. Meadow, E. Newport, M. Shatz, M. Silverstein, and T. Trabasso for comments and R. Church, E. Eichen, M. Morford, and D. Unora for videotape coding. Supported by NSF grant BNS 77-05990 and by grants from the Spencer Foundation.

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Metabolic Detoxification: Mechanism of Insect Resistance to Plant Psoralens

Abstract. *Larvae of the black swallowtail butterfly,* Papilio polyxenes *Stoll, forage successfully on plants that contain high levels of photosensitizing psoralens. These insects rapidly detoxify psoralens, particularly in the midgut tissue prior to absorption, with the result that appreciable levels of unmetabolized phototoxin do not enter the body circulation where deleterious light-induced interactions with dermal or subdermal tissues would occur.*

Psoralens (linear furocoumarins) are photoactive compounds that readily alkylate DNA when activated by longwave ultraviolet light (*1*). The biological activities of psoralens include uses in human medicine (*1, 2*) and they pose significant toxicological risks to man and other organisms (*3, 4*). Psoralens occur naturally in plant species, where they act as generally effective deterrents against feeding by insects and other herbivores (*4, 5*). Certain insects, however, particularly the larvae of some butterflies of the family Papilionidae, feed successfully and preferentially on plants that contain psoralens (*6*). The mechanism of insect resistance to the phototoxic effects of these chemicals has heretofore not been considered and is the subject of our report. We have shown that larvae of the black swallowtail butterfly, *Papilio polyxenes* Stoll (Lepidoptera: Papilionidae), rapidly degrade 8-methoxypsoralen (xanthotoxin) to nonphotosensitizing metabolites in the midgut tissue prior to absorption; thus, appreciable levels of the intact phototoxin are not available for light-induced interactions with body tissues. In contrast, identically exposed larvae of a psoralen-susceptible insect, the fall armyworm, *Spodoptera frugiperda* J. E. Smith (Lepidoptera: Noctuidae), metabolize xanthotoxin at a much slower rate, with the result that levels of the absorbed photosensitizer in *S. frugiperda* are more than 50 times greater than those seen in *P. polyxenes*.

While collecting plants for studies of the toxicology and psoralen chemistry of the livestock photosensitizing weed *Thamnosma texana* (Gray) (Rutaceae) (*7*), we observed larvae of *P. polyxenes* feeding on populations of *T. texana* in direct sunlight in Medina County, Texas. The larvae were collected and reared to pupae in the laboratory on harvested, moistened *T. texana*. Emerging adults were fed a mixture of honey and water, and 2- to 3-day-old females were subsequently mated with 1- to 2-day-old males. Sprigs of fresh parsley from a local supermarket were provided for oviposition, and the hatched larvae were continuously fed a diet of fresh parsley. Newly hatched larvae of a laboratory colony of *S. frugiperda*, a highly polyphagous insect that feeds on many plant hosts other than psoralen-rich species (*8*), were transferred to and reared on fresh parsley.

A ^{14}C-labeled preparation of xanthotoxin, a common plant psoralen (*9*), was applied in acetone solution to small twigs of parsley, the solvent was allowed to evaporate, and the treated twigs were fed to last instar larvae of either insect species that had been starved for 2 hours (*10*). The dosages were equivalent to 5 μg/g, tailored to the individual prestarvation weight of each larva. Typically, larvae of both *P. polyxenes* and *S. frugiperda* consumed the entire dosage within 5 to 15 minutes. At 1.5, 3, 6, 12, or 24 hours after treatment, the gut was carefully dissected from the body, and the gut and contents, body, and any excreta eliminated during the period after treatment were analyzed separately for [^{14}C]xanthotoxin and its metabolites (*11*).

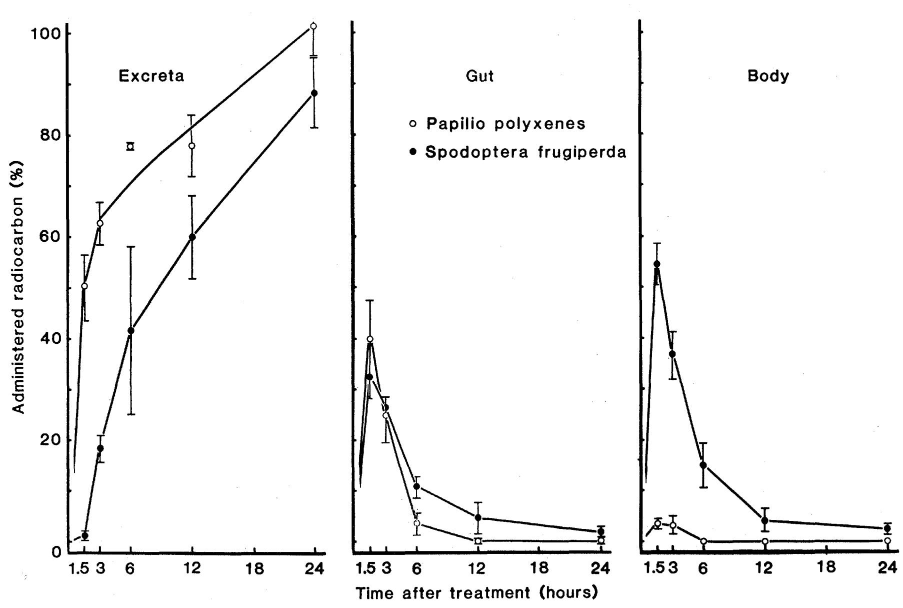

Fig. 1. Patterns of ^{14}C excretion and distribution in last instar larvae of *Papilio polyxenes* and *Spodoptera frugiperda* after oral treatment with [^{14}C]xanthotoxin at 5 μg/g. Data points are means (N = 3 or more) with standard deviations indicated by the bars.

Elimination of ^{14}C after oral treatment with [^{14}C]xanthotoxin is much more rapid in *P. polyxenes* than in *S. frugiperda* (Fig. 1). Within 1.5 hours, 50 percent of all the administered ^{14}C is recovered in