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Chapter 12

Levels of Structure in a Communication System Developed without a Language Model

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The Resilience of Language Development

Language is a robust phenomenon mastered by children experiencing a wide range of environments (cf. Wimsatt, 1981). Despite great variability in patterns of child–caretaker communications (e.g. Miller, 1982; Ochs, 1982; Pye, 1986; Schieffelin, 1979), virtually all children in all cultures master the language to which they are exposed. However, there do appear to be limits on the robustness of language development in children. If, for example, a child is not raised by humans (e.g., Lane, 1977) or is raised by humans under inhumane conditions (e.g., Curtiss, 1977), severe breakdowns in language development will occur.

Moreover, not all properties of language appear to be equally robust in the face of variations in environmental conditions. Certain properties of language have been found to develop in environments that deviate dramatically from typical language-learning environments, while other properties of language have not. For example, Sachs and her colleagues (Sachs et al., 1981; Sachs and Johnson, 1976) studied the language development of a hearing child who was exposed to an impoverished model of English by his deaf parents and found that this child developed some of the properties of English but failed to develop others. Thus, the child's dearth of linguistic input appeared to have had differential effects on his language development.

By observing the effects of variations in the linguistic environment on the development of language in children, we can hope to determine which properties of language will develop in child language across a wide range of linguistic environments, and which properties of language will develop in only a relatively narrow range of environments.

In our work, we focus on isolating those properties of language whose development can withstand wide variations in learning conditions—the "re-

silient" properties of language. In an attempt to determine which properties of language can be developed by a child under one set of degraded input conditions, we observe children who have not been exposed to any conventional linguistic input. The children we study are deaf with hearing losses so severe that they cannot naturally acquire oral language. In addition, these children are born to hearing parents who have chosen not to expose them to a manual sign language. We have found that these deaf children, despite their impoverished language learning conditions, develop a gestural communication system that is structured in many ways like the communication systems of young children learning language in ordinary linguistic environments (Feldman et al., 1978; Goldin-Meadow, 1979, 1982; Goldin-Meadow and Mylander 1983, 1984).

In our previous work we demonstrated that the gesture systems our deaf subjects develop are structured at the sentence level of analysis; specifically, order and deletion patterns are identifiable *across* gestures in a sentence. However, natural languages, both signed and spoken, are known to be structured not only at the sentence level but also at the word or sign level. If a hierarchy of structured levels is common to all natural languages, it becomes important to ask whether the deaf children in our studies display such hierarchical structure in their gestural communication as well. In other words, we ask whether hierarchical structure is also a "resilient" property of language.

The primary objective of this study is to determine whether the deaf children's gesture systems are structured at this second level, the level of the word or sign. Thus, we ask whether structure exists *within* gestures as well as across them, and, if so, which aspects of structure at this level can be developed by a child without the benefit of a conventional language model.

Background

The sign languages of the deaf are autonomous languages that are not derivatives from the spoken languages of hearing cultures (Bellugi and Studdert-Kennedy, 1980; Klima and Bellugi, 1979; Lane and Grosjean, 1980). A sign language such as American Sign Language (ASL) is a primary linguistic system passed down from one generation of deaf people to the next and is a language in the full sense of the word. Like spoken languages, ASL is structured at syntactic (Fischer, 1975; Liddell, 1980), morphological (Fischer, 1973; Fischer and Gough, 1978; Klima and Bellugi, 1979; Newport, 1981; Supalla, 1982; Supalla and Newport, 1978), and "phonological" (Battison, 1974; Lane et al., 1976; Stokoe, 1960) levels of analysis.

Deaf children born to deaf parents and exposed from birth to a conventional sign language such as ASL have been found to acquire that language naturally; that is, these children progress through stages in acquiring sign language similar to those of hearing children acquiring a spoken language (Caselli, 1983; Hoffmeister, 1978; Hoffmeister and Wilbur, 1980; Kantor, 1982; Newport and Ashbrook, 1977). Thus, in an appropriate linguistic environment, in this case, a signing environment, deaf children are not handicapped with respect to language learning.

However, 90% of deaf children are not born to deaf parents who could provide early exposure to a conventional sign language. Rather, they are born to hearing parents who, quite naturally, tend to expose their children to speech (Hoffmeister and Wilbur, 1980). Unfortunately, it is extremely uncommon for deaf children with severe to profound hearing losses to acquire the spoken language of their hearing parents naturally, that is, without intensive and specialized instruction. Even with instruction, deaf children's acquisition of speech is markedly delayed when compared either to the acquisition of speech by hearing children of hearing parents or to the acquisition of sign by deaf children of deaf parents. By age 5 or 6, and despite intensive early training programs, the average profoundly deaf child has only a very reduced oral linguistic capacity (Conrad, 1979; Meadow, 1968; Mindel and Vernon, 1971).

In addition, unless hearing parents send their deaf children to a school in which sign language is used, these deaf children are not likely to be exposed to conventional sign input. Under such nonpropitious circumstances, these deaf children might be expected to fail to communicate at all, or perhaps to communicate only in nonsymbolic ways. This turns out not to be the case.

Previous studies of deaf children of hearing parents have shown that these children spontaneously use gestural symbols to communicate even if they are not exposed to a conventional sign language model (Fant, 1972; Lenneberg, 1964; Moores, 1974; Tervoort, 1961). These gestures are conventionally referred to as "home sign." Most of our work has focused particularly on the *structural* aspects of deaf children's home sign.

Syntactic Properties of Deaf Children's Home Sign Systems: Structure across Signs

The heuristic we have adopted in describing the deaf children's home sign systems has been to determine which of the properties of early child language can be found in the deaf children's gesture systems. We have observed the home sign of 10 deaf children of hearing parents and found that all 10 children developed gesture systems comparable in many respects to early child language (Feldman et al., 1978; Goldin-Meadow, 1979, 1982; Goldin-Meadow and Feldman, 1975, 1977; Goldin-Meadow and Mylander, 1984). In addition, we investigated the possibility that the deaf children might have learned their home sign systems from their hearing parents. In particular, we asked whether the parents, in an effort to communicate with their children, generated a structured gesture system that their children then imitated, or whether the parents shaped the structure of their children's gestures by patterning their responses to those gestures. We found no evidence supporting either of these hypotheses (Goldin-Meadow and Mylander, 1983, 1984).

The deaf children in our studies developed gestures that function as words do

in the systems of hearing children learning conventional spoken languages, and as signs do in the systems of deaf children learning conventional signed languages (e.g., ASL). The children in our studies produced two types of gestures: (1) deictic signs used to refer to people, places, or things (e.g., a pointing sign at a snack), and (2) characterizing signs used to refer to actions or attributes (e.g., a fist held at the mouth accompanied by chewing [EAT]).[1] In addition, the deaf children combined their signs into strings that function as do the sentences of early child language in two respects: (1) The deaf children's sign sentences express the semantic relations typically found in early child language, with characterizing signs representing the predicates and deictic signs representing the arguments of those semantic relations. (2) The deaf children's sign sentences are structured as are the sentences of early child language; specifically, there are order and deletion patterns identifiable across signs (or words) in a sentence (e.g., the sign for the patient[2] role [snack] is likely to precede the sign for the act predicate [eat]). Moreover, the children exhibited the property of recursion in their sign systems and generated novel, complex sentences (containing at least two propositions) from combinations of simple one-proposition sentences. For example, one child pointed at a tower, produced the HIT sign [fist swatting in air] and then the FALL sign [flat palm flops over in air] to comment on the fact that he had hit [act_1] the tower and that the tower had fallen [act_2]).

In sum, in our previous work we found that deaf children, even without the benefit of a conventional linguistic model, can develop gestural communication systems that display some of the structural properties of early child language—in particular, structural properties at the level of the sentence. Thus, it appears that the human child has strong biases to communicate using strings of lexical items and to structure those strings in language-like ways.

Structure at a Second Level?

As described above, our previous work focused on the structural regularities across signs in our deaf subjects' gesture sentences. For the purposes of this "syntactic" analysis, we treated each sign as the minimal meaning-bearing unit. However, in the process of examining the corpus of signs produced by each child, we began to notice certain subsign forms (e.g., handshape and motion) that seemed to be associated with consistent meanings and that, furthermore, seemed to recur in the composition of different signs. For example, one child used the same motion form (moving the hand to and fro) to mean "movement back and forth" in at least two different signs: once with a fist handshape (resembling a person's hand moving a knife back and forth) and a second time with a flat palm handshape held vertically (resembling the knife itself moving back and forth). In addition to suggesting that the child can focus either on a person acting on an object or on the object itself in generating a sign, this example also suggests that handshape and motion might be separable forms associated with distinct meanings that combine to form signs in the child's gesture system; that is, the example suggests that handshape and motion function as morphemes in the deaf child's gesture system.

Examples of this sort do not by themselves provide evidence of a *system* of handshape and motion morphemes; selected examples may not be representative of the way in which the child constructs his entire lexicon. In order to argue that the deaf child's signs are consistently divisible into handshape and motion morphemes, we must review the entire corpus of characterizing signs and ask whether the set of signs meets the following criteria for structure at the level of the sign:

1. Is there a limited set of discrete handshape and motion forms in the child's corpus of signs? i.e., are the forms categorical rather than continuous?
2. Is a particular handshape or motion form consistently associated with a particular meaning (or set of meanings) throughout the corpus of signs? i.e., is each handshape and motion form meaningful?
3. Does a particular handshape or motion form/meaning pairing appear in more than one sign? i.e., is a particular form/meaning pairing an independent morpheme that can combine with other morphemes in the system—is the system combinatorial.

The present chapter focuses on structure across components (morphemes) within a sign; that is, we focus on structure at the "morphological" level. Our search for morphological structure in the deaf children's gesture systems is guided particularly by recent research on morphology in ASL. We begin by reviewing the findings of this literature that are relevant to our analyses.

Morphological Properties of the Deaf Child's Home Sign System: Structure within the Sign

Early research in ASL suggested that verbs in ASL, unlike verbs in spoken languages, appeared to be continuously varying forms constructed on the basis of analog representations of real-world events (DeMatteo, 1977). In other words, ASL verbs were thought not to be divisible into component parts, but rather were considered unanalyzable lexical items that mapped, as wholes, onto events in the world. Subsequently, verbs in ASL (particularly, the mimetic verbs of motion) have been more accurately described as combinations of a limited set of discrete morphemes (McDonald, 1982; Newport, 1981; Supalla, 1982). For example, to describe a drunk's weaving walk down a path, an ASL signer would *not* represent the idiosyncrasies of the drunk's particular meanderings, but would instead use a conventional morpheme representing random movement (i.e., a side-to-side motion) in conjunction with a conventional morpheme representing change of location. Mimetic verbs in ASL have been shown to be constructed from discrete sets of morphemes and to include, at a minimum, a motion

morpheme combined with a handshape morpheme (McDonald, 1982; Newport, 1981; Supalla, 1982).

Morphemes in ASL (as in spoken languages) have been organized into frameworks or matrices of oppositions, referred to as "paradigms" (cf. Matthews, 1974). For example, the motion form "linear path" (representing change of location along a straight path) can be combined with any number of hand forms representing agents or actors (e.g., inverted V = human; a bent inverted V = an animate nonhuman; thumb + two fingers held sideways = a vehicle). These combinations create a set of signs whose meanings are predictable from the meanings of the individual motion and handshape elements (i.e., a human moves along a straight path, an animate nonhuman moves along a straight path, a vehicle moves along a straight path). In another example, a different motion form (e.g., "arc path," representing change of location along an arced path such as a jump forward) can be combined with any of these same handshape morphemes to create a set of signs whose meanings are also systematic combinations of the component parts of each sign (e.g., a human jumps forward, an animate nonhuman jumps forward, a vehicle jumps forward). Thus, many of the verbs of ASL can be described in terms of a combination of handshape and motion morphemes that together form complete paradigmatic sets.

To determine whether our deaf subjects' gestures can also be characterized by systematic combinations of meaningful forms, we selected one of our original subjects (David) and analyzed the characterizing signs (i.e., the mimetic signs) he produced during naturalistic play sessions videotaped in his home when he was 2;10, 2;11, 3;0, 3;3, 3;5, 3;11, and 4;10.[3] These ages span the age range during which both deaf (Supalla, 1982) and hearing (MacWhinney, 1976) children learning conventional languages have typically already begun to acquire certain morphemic distinctions.

The videotapes of David were coded initially at the sign level according to a system described in detail in Goldin-Meadow (1979) and Goldin-Meadow and Mylander (1984). We then coded each characterizing sign produced during these sessions in terms of its handshape and motion. Reliability between two independent coders ranged from 85 to 95% agreement for handshape and from 83 to 93% agreement for motion.

We begin by analyzing, first, the forms and meanings of the handshapes David used in his signs and, then, the forms and meanings of the motions in those signs. We next describe the combinations of handshapes and motions that occurred in the corpus of David's signs. Finally, we describe how motions combined with other motions in David's signs.

Handshape Morphemes

Handshape Forms. Following Supalla (1982) and McDonald (1982), we coded each handshape according to four dimensions: the shape of the palm, the distance between the fingers and the thumb, the number of fingers extended, and the presence or absence of spread between the fingers. At first, we coded handshapes continuously along each dimension without establishing a priori either discrete categories or boundaries. Thus, for example, we wrote down the exact distance (in inches) between the fingers and thumb of a particular handshape and did not try to force that handshape into a limited set of thumb–finger distances. We found, however, that David used only a restricted number of values on each of the four dimensions. Table 1 displays the five most frequent handshapes David used on these tapes described in terms of the relevant dimensions. These five handshapes accounted for 98% of all of the handshapes David produced ($N = 472$).

The remaining 2% of David's handshapes not represented in Table 1 were V (two fingers spread apart and extended), L (thumb and forefinger extended at right angles to each other), Thumb (thumb extended), F (thumb and finger touching with the other three fingers extended in the "okay" sign), and W (three fingers spread apart and extended). Each of these infrequently produced handshapes was used to represent only one object throughout the tapes (e.g., the V was used to represent scissors, the L was used to represent a gun). We saw no evidence that these handshapes participated in a generative way in David's sign system and, as a result, we eliminated them from further analyses.

Handshape Form/Meaning Mapping. We next determined whether David's handshapes mapped in any systematic way onto categories of meanings. We found that David used his handshapes in two ways: (1) to represent a HAND as it manipulates an object, or (2) to represent the OBJECT itself. For example (as described above), to describe a picture of a knife, David produced a Fist handshape (with a back and forth movement) that mirrors a cutter's hand manipulating a knife, and thus is an instance of a HAND handshape. In contrast, to again describe the knife, David produced in a separate sentence a Palm handshape held perpendicular to the table (with the same back and forth movement), mirroring the flat shape of the knife itself, and, therefore, meeting the criterion for an OBJECT handshape. The same hand/finger configuration could be used to represent either a HAND or an OBJECT morpheme in David's

Table 1. Description of Handshape Forms

Handshape Form	*Description*
Fist	Fingers and thumb curled into palm
O	Index finger or four fingers bent toward thumb with ½ inch or less between the thumb and finger(s)[a]
C	Index finger or four fingers bent toward thumb with 3 inches between the thumb and finger(s)[a]
Palm	Four fingers extended
Point	Index finger extended

[a]If only the index finger was bent toward the thumb in the O and C handshapes, the other three fingers were either curled into the palm or held sloppily in an untensed manner.

system. On one occasion, David used a C handshape to represent handling a cup—where the handshape mirrored the handgrip around the cup [HAND]. At another time, he used the same C handshape to represent the shape of a cowboy's curved legs as the cowboy sits astride a horse [OBJECT]. Orientation of the hand with respect to the motion was crucial in determining whether the hand represented a HAND handshape or an OBJECT handshape. In the above cowboy example where the C was used as an OBJECT handshape, the fingers and palm of the C handshape point downward as the motion descends, mirroring the shape of the cowboy's legs as they go around the horse. If, however, the C were perpendicular to the motion (oriented as a person's hand would be if it were placing the cowboy on the horse), the handshape would have been considered a HAND handshape rather than an OBJECT handshape.

To determine the meaning of each handshape form, we first listed all of the objects represented by each handshape form used with either a HAND or OBJECT meaning in the one-motion signs (signs that contained only a single motion) David produced during one session, the session at age 3;11. We then determined whether the set of objects associated with a particular handshape form could be said to share a common attribute or set of attributes. If so, we took that common core to be the meaning of the particular handshape form. We then used these form/meaning pairings to code the videotapes of the six remaining sessions.

Table 2 describes the meanings found to be associated with the HAND and OBJECT handshape forms in the session at age 3;11, as well as examples of the objects represented by each handshape form/meaning pairing. Table 2 also presents the total number of different types of objects represented by each form/meaning pairing and, in parentheses, the total number of times each form/meaning pairing was used throughout the seven videotaped sessions.[4] We found that 367 (95%) of the 386 handshapes David produced in his one-motion signs during the seven videotaped sessions could be classified into the form/meaning categories listed in Table 2. In addition, 68 (91%) of the 75 handshapes in David's two-motions signs (signs that contained two motions concatenated without a break so that both appeared to be within the same sign) were also found to conform to the form/meaning categories established on the basis of the one-motion signs produced during the 3;11 session. Note that the Palm and Point handshapes were each used to represent more than one class of objects (e.g., the OBJECT Palm was used to represent (1) flat, wide objects, (2) many small particles, and (3) vehicles and animate objects); each of these classes is considered to be a distinct morpheme. Exceptions to Table 2 consisted of form/meaning mismatches, such as a Fist form used to represent handling a small, *short* (rather than a long) object (e.g., a knob on a toy), or a Palm form used to represent a round inanimate object (e.g., a ball moving forward).

It is important to note that David's HAND morphemes were not always accurate representations of the way a hand grasps a particular object in the real world, nor were his OBJECT morphemes precise mimetic reconstructions of real world objects. For example, the same HAND form (the Fist) was used to represent grasping a balloon string, a drumstick, and handlebars—grasping actions that require considerable variety in diameter in the real world. David therefore appeared not to distinguish objects of varying diameters within the Fist category. However, he did use his handshapes to distinguish objects with small diameters *as a set* from objects with large diameters (e.g., a cup, a guitar neck, the length of a straw) that were represented by a C hand.

As another example, David used the same OBJECT form (the O) to represent a round hat, a Christmas tree ball, and a bubble—objects that vary in size in the real world. David did not appear to distinguish objects of varying sizes within the

Table 2. Meanings of Handshape Forms[a]

	HAND Morphemes		*OBJECT Morphemes*	
Form	*Meaning*	*Types (Tokens)*	*Meaning*	*Types (Tokens)*
Fist	Handle small, long object (e.g., spoon, drumstick, balloon string, handlebar)[b]	19 (70)	Bulky object (hammer head)	1 (2)
O	Handle small object (e.g., crank, shoe lace)[b]	31 (102)	Round compact object (e.g., round hat, tree ball, bubble)	6 (17)
C	Handle large object (e.g., cup, horn, guitar neck)[b]	11 (20)	Curved object (e.g., cowboy's legs around a horse, turtle)	5 (7)
Palm	Handle flat surface (e.g., sides of toy bag, chair back)	12 (30)	Flat wide object (e.g., flag, bird wings)	9 (43)
	Handle many small surfaces (xylophone keys)	1 (3)	Many small particles (e.g., snow)	6 (9)
			Vehicle or animate object (e.g., car, sister, Santa, plane)	13 (26)
Point	Handle small surface (trigger)	1 (2)	Thin straight object (e.g., straw, bubble wand, pinwheel)	6 (12)
			Object of any shape (e.g., bear, penny, Susan)	13 (24)

[a]The table contains the handshapes found in David's one-motion signs during the seven videotaped sessions. The first number represents the number of different types of objects represented by the handshape, and the number in parentheses represents the total number of times the handshape was used for that meaning.
[b]Small = ≤2 inches in diameter; large = >2 inches in diameter; long = >5 inches in length.

O category, but rather appeared to categorize them all as round objects. However, David did distinguish these round objects *as a set* from curved objects (e.g., a turtle's back, a cowboy's legs around a horse) that were represented by a C hand. Overall, David thus appeared to consign handshapes to discrete categories, rather than utilize analog representations of "real world" objects.

Motion Morphemes

Motion Forms. We found that David used eight different types of motions, as well as a no-motion form, in his signs (Table 3). The motions were defined in terms of the type of trajectory traced by the hand (linear path, arced path, circle) or the motions of the hand in place (revolve, open/close, bend, wiggle). In addition, arcs were distinguished in terms of length of path (< 7 inches v. > 7 inches) and directionality (unidirectional vs. bidirectional). These motion forms account for 100% of the signs David produced during these sessions ($N = 514$).

Motion Form/Meaning Mapping. To determine whether each of David's nine motion forms was associated with a particular class of meanings, we began by listing all of the actions David represented with each of the nine motion forms in the one-motion signs he produced during the session at age 3;11. We then determined whether the actions associated with a particular motion form shared certain common attributes. If so, we took that common core to be the meaning of the particular motion form, and used the resulting set of form/meaning pairings to code the videotapes from the remaining six sessions.

Table 4 presents the meanings of the motion forms David produced in his one-motion signs during the session at age 3;11. The numbers in the table represent the total number of different types of actions represented by each form/meaning pairing, and (in parentheses) the total number of times each motion form/meaning pairing was used over the course of the seven videotaped sessions.

We found that David used his motion forms to represent four different types of change in the state of an object: change of location, change of position, change of

Table 3. Description of Motion Forms

Form	*Type of Motion*
Linear	Hand moves in a straight path
Long arc	Hand moves in an arced path >7 inches in length unidirectionally
Short arc	Hand moves in an arced path <7 inches in length unidirectionally
Arc to and fro	Hand moves in an arced path of any length bidirectionally
Circular	Hand moves in circle, wrist or fingers revolve
Open/close	Hand or fingers open and/or close
Bend	Hand or fingers bend
Wiggle	Fingers wiggle
No motion	Hand held in place

Table 4. Meanings of Motion Forms[a]

Type of Motion	*Form*	*Meaning*	*Types (Tokens)*
Change of location	Linear	Change of location by moving along a path	16 (34)
	Long arc	Change of location by moving along a path, typically to or from a particular endpoint	19 (24)
Change of position	Arc to and fro	Reposition by moving back and forth	29 (114)
	Circular	Reposition by moving in a circle or rotating around an axis	15 (37)
	Short arc	Reposition (or reorient) in place; reposition in order to affect another object; or reposition with respect to another object or place	33 (71)
Change of shape	Open/close	Open/close, expand/contract, or flicker on/off	9 (16)
	Bend	Bend at a joint	2 (5)
	Wiggle	Wiggle back and forth	2 (3)
No change	No motion	Hold in place or exist	29 (91)

[a]The table contains the motions found in David's one-motion signs during the seven videotaped sessions. The first number represents the number of different types of actions represented by the motion, and the number in parentheses represents the total number of times the motion was used for that meaning.

shape, and no change. He used the Linear and Long Arc forms to represent *change of location* along a path, either of an object (or person) moving on its own (that is, an intransitive motion, e.g., bubble go up, we go down), or an object being moved by a person (a transitive motion, e.g., move coat, scoop spoon). Although both forms were used to represent change of location, the Long Arc was typically used to represent a change of location bounded by a particular endpoint (e.g., penny arc forward [to a bank]), while the path represented by the Linear form could either be open-ended (e.g., bubble go upward) or bounded by an endpoint (e.g., we go down [to the bottom of the stair]).

David used the Arc To and Fro, Circular, and Short Arc forms to represent the *change of position* either of an object (or person) repositioning itself (that is, an intransitive motion, e.g., wheel tip-over), or an object being repositioned by a person (a transitive motion, e.g., turn-over clay). A change of position involved bidirectional repositioning around a center-point (the Arc To and Fro form, e.g., wings flap, jiggle handlebars side-to-side), unidirectional repositioning around an axis or center-point (the Circular form, e.g., wheel rotate, turn crank), or unidirectional repositioning having no center-point (the Short Arc form). There were three types of meanings conveyed by the Short Arc form: repositioning in the same spot (e.g., wheel tip-over), repositioning an object to affect another

object (e.g., swing hammer [to knock tower], shake envelope [to release contents]), or repositioning an object with respect to another object or a place, either to remove the object (e.g., pick-up bubble jar [off table]) or to place the object (e.g., hook treelights [onto Christmas tree], push-down box lid [onto bottom of box]).

David used the Open/Close, Bend, and Wiggle forms to represent the *change of shape* either of an object altering its own form (an intransitive motion, e.g., bubble expands, fish bends [to swim]), or a hand altering its shape on an object (a transitive motion, e.g., hand closes around toy bulb, fingers wiggle to strike keys). The Open/Close form was used to represent an object (or hand) opening or closing (e.g., claw closes, hand closes [around toy]), expanding or contracting (e.g., bubble expands), or flicking on and off (e.g., treelights flicker). The Bend form was used to represent an object bending at a joint (e.g., fish bends). The Wiggle form was used to represent an object (or hand) wiggling (e.g., snow flutters, fingers wiggle [to strike piano keys]).

Finally, David used the No-Motion form to represent *no change* in an object as it is held in place (e.g., hold bubble-wand [at mouth]) or as it exists (e.g., puzzleboard exists, bubble exists).

We found that 395 (90%) of the 439 motions in the one-motion signs David produced during the seven videotaped sessions could be classified according to the form/meaning pairings listed in Table 4. In addition, 69 (92%) of the 75 motions in David's two-motion signs conformed to the form/meaning pairings established on the basis of the one-motion signs produced during the session at age 3;11. Exceptions to Table 4 consisted of form/meaning mismatches, such as a Short Arc form used to represent the path of a change of location (e.g., a turtle moving forward along a path), or a Long Arc form used to represent an object being repositioned (e.g., swinging a hammer).

Handshape and Motion Combinations

We have shown that David's signs can be described in terms of handshape morphemes (i.e., handshape form/meaning pairings) and motion morphemes (i.e., motion form/meaning pairings). We now attempt to demonstrate that the signs themselves were in fact composites of handshape and motion morphemes rather than one unanalyzed whole, i.e., that handshape and motion are separable units. Since signs are composed of hands moving in space, it is not possible to find handshapes that are actually separated from their motions. Nevertheless, if we find a handshape that is not uniquely associated with one sign but rather is combined with several different motions in different signs, we then have evidence that the handshape may be an independent unit in David's system. Similarly, if a motion is combined with different handshapes in different signs, we infer evidence for the separability of that motion. We will consider first David's HAND handshape morphemes in combination with motion morphemes

and then David's OBJECT handshape morphemes in combination with motion morphemes.

HAND Handshape Morphemes Combined with Motion Morphemes. Table 5 displays examples of the HAND handshape morphemes combined with each of the nine motion morphemes. Empty cells in Table 5 represent handshape/motion combinations that David did not use at all during these sessions. Two HAND morphemes—the Palm (Many Surfaces) and the Point—are not shown at all in Table 5 because the Palm (Many Surfaces) occurred with only two motion morphemes and the Point did not occur with any well-formed motion morphemes. The numbers in Table 5 represent the number of types of events represented by each pairing of a HAND handshape with one of the nine motions; the numbers in parentheses represent the total number of times a particular handshape occurred with a particular motion. The table contains David's one-motion signs, excluding those that were exceptions to either Table 2 (handshape form/meaning pairings) or Table 4 (motion form/meaning pairings). In Table 5 the handshapes represent an actor's hand shaped on or around a patient, and the motions represent events in which an actor manipulates a patient (i.e., transitive events).

Note that most of David's HAND handshape morphemes could be found in combination with more than one motion morpheme, and vice versa. As a result, David's signs can be said to conform to a framework or system of contrasts. As an example of how the meanings of David's signs systematically contrasted with

Table 5. HAND Handshapes Used in Combination with Motions[a]

	Fist	*O*	*C*	*Palm*
Change of location Linear	—	—	—	Change the location of an object with a large flat surface 1(1), e.g., push toys away
Long arc	Change the location of a small long object 1(1),[b] e.g., scoop utensil	Change the location of a small object of any length 1(1), e.g., scoop spoon	—	Change the location of an object with a large flat surface 1(2), e.g., push chair (to wall)

(*cont.*)

Table 5. HAND Handshapes Used in Combination with Motions[a] *(cont.)*

	Fist	*O*	*C*	*Palm*
Change of position				
Short arc	Reposition a small long object 6(12), e.g., pull out newspaper	Reposition a small object of any length 10(20), e.g., take out bubble wand	Reposition a large object of any length 2(2), e.g., pick up bubble jar	Reposition an object with a large flat surface 2(5), e.g., lift up large toy bag
Arc to and fro	Move a small long object to and fro 7(28), e.g., wave balloon string back and forth	Move a small object of any length to and fro 7(42), e.g., move crayon back and forth (to draw)	Move a large object of any length to and fro 1(1), e.g., shake salt shaker up and down	Move an object with a large flat surface to and fro 5(8), e.g., swing child back and forth holding his rear-end
Circular	Move a small long object in a circle 1(1), e.g., wave flag pole in circle	Move a small object of any length in a circle 5(8), e.g., turn crank	Move a large object of any length in a circle 4(10), e.g., twist jar lid	—
Change of shape				
Open/close	Grasp or release a small long object 1(1), e.g., grasp mower handle	Grasp or release a small object of any length 2(2), e.g., squeeze bulb toy	—	—
Bend	—	—	—	—
Wiggle	—	—	—	—
No change				
No motion	Hold a small long object 6(16), e.g., hold handlebars	Hold a small object of any length 9(24), e.g., hold bubble wand	Hold a large object of any length 3(6), e.g., hold horn	—

[a]Two HAND handshapes, Palm (many surfaces) and Point, are omitted from the table because they occurred infrequently. Palm (many surfaces) occurred with two motions (Arc to and Fro and No Motion), and Point occurred only with motions that were not well formed.

[b]The first number represents the number of different types of events represented by the handshape/motion combination. The number in parentheses represents the total number of tokens. Only one-motion signs are included in the table.

one another, the C handshape was used in combination with the Short Arc motion to mean "change the position of large object by hand" (e.g., pick-up bubble jar). The same Short Arc motion when used in combination with a different handshape (the Fist) meant "change the position of a small, long object by hand" (e.g., pull-out newspaper). In contrast, the same Fist handshape when combined with a different motion (the Arc To and Fro) meant "move a small, long object to and fro by hand" (e.g., wave balloon string back and forth).

Whereas change-of-position and no-change motion morphemes each formed a relatively complete matrix or paradigm with the HAND morphemes, certain of the other handshape/motion combinations were produced only infrequently. For example, the Linear motion morpheme occurred with only one HAND morpheme despite the fact that the Long Arc motion (which is comparable in meaning to the Linear motion) occurred with three of the four HAND morphemes. In addition, change-of-shape motions were found in only 2 of the 12 possible handshape/motion combinations shown in Table 5.

OBJECT Handshape Morphemes Combined with Motion Morphemes. David used OBJECT handshapes in three different types of signs: (1) signs describing an intransitive event in which an actor (animate or inanimate) propels itself and does not affect a patient, where the handshape represents a characteristic of the actor, e.g., a C handshape used with a Linear motion to describe a turtle moving forward; (2) signs describing a transitive event in which an actor affects a patient, where the handshape represents a characteristic of the patient, e.g., a C handshape used with a Short Arc motion to describe the curved shape of a cowboy's legs as someone places the cowboy on a horse; and (3) signs describing a static object, e.g., a C handshape used with a No-motion form to describe the arced shape of a block. David produced 72 (56%) signs of type 1 (OBJECT handshapes with motions representing intransitive events), 26 (20%) signs of type 2 (OBJECT handshapes with motions representing transitive events), and 31 (24%) signs of type 3 (OBJECT handshapes with the no-motion morpheme representing attributes of objects). We describe each of these types of signs with OBJECT handshapes in turn.

Intransitive meanings. Table 6 presents examples of the OBJECT morphemes combined with the nine motion morphemes when those motions were used to represent events in which an actor or mover propels itself and does not affect a patient, i.e., intransitive events. As in Table 5, empty cells in Table 6 represent handshape/motion combinations that David did not use at all during these sessions. Two OBJECT morphemes—the Fist and the O—are not included in Table 6 because they did not occur with motions describing intransitive events. The numbers in Table 6 represent the number of types of intransitive events represented by each pairing of an OBJECT handshape with one of the nine motions; the numbers in parentheses represent the total number of times a particular handshape occurred with a particular motion. The table contains David's one-motion signs, again excluding the exceptions to Tables 2 and 4.

Table 6. OBJECT Handshapes Used in Combination with Motions[a]

	C	PALM (flat and wide)	PALM (animal/vehicle)	PALM (particles)	POINT (thin-straight)	POINT (neutral)
Change of location						
Linear	Curved object changes location 2(2),[b] e.g., turtle go	Flat wide object changes location 1(1), e.g., skate glide	Animal or vechicle changes location 10(13), e.g., Santa goes down	—	Thin-straight object changes location 1(2), e.g., penny flies through air	Object of any shape changes location 3(7), e.g., cookie goes down
Long arc	Curved object changes location 1(1), e.g., turtle go	Flat wide object changes location 1(1), e.g., skate glide	Animal or vehicle changes location 4(4) e.g., plane goes up	Particles change location 1(1), e.g., snow falls down	Thin-straight object changes location 1(1), e.g., penny goes (to bottle bank)	Object of any shape changes location 2(4), e.g., Susan moves to couch
Change of position						
Short arc	—	Flat wide object repositions itself 1(1), e.g., butterfly wings come together	Animal or vehicle repositions itself 2(2), e.g., sister sits	Particled object repositions itself 1(1), e.g., wheel tips over	—	—
Arc to and fro	—	Flat wide object moves to and fro 4(17), e.g., birdwings flap	—	—	—	—
Circular	—	—	—	—	—	—
Change of shape						
Open/close	Curved object opens and/or closes 1(1), e.g., bubble expands	Flat wide object opens and/or closes 1(1), e.g., flat claws curl	—	Particles open and/or close 2(4), e.g., treelights flicker	—	—
Bend	—	Flat wide object bends 1(2), e.g., birdwings bend	Animal or vehicle bends 1(3), e.g., fish bends (to swim)	—	—	—
Wiggle	—	—	—	Particles go up and down 1(1), e.g., snow flutters	—	—
No change						
No motion	—	—	—	—	—	—

[a] Two OBJECT handshapes, Flat and O, are omitted from the table because they did not occur with motion morphemes representing intransitive events.
[b] The first number represents the number of different types of events represented by the handshape/motion combination. The number in parentheses represents the total number of tokens. Only one-motion signs are included in the table.

Most of David's OBJECT morphemes could be found in combination with more than one motion morpheme, and vice versa. Thus, David's signs composed of OBJECT handshapes and motions also appeared to fit into a framework or system of contrasts. As an example of how the meanings of these signs contrasted systematically with one another, the C handshape was combined with the Linear motion to mean "a curved object changes location" (e.g., a turtle moves forward). This same Linear motion when combined with a different handshape, Palm (Vehicle/Animate), meant "a vehicle or animate being changes location" (e.g., Santa goes down; car goes forward). In contrast, the same Palm handshape when combined with a different motion (the Short Arc) meant "a vehicle or animate being repositions itself" (e.g., a sister sits). The OBJECT morphemes in David's signs thus formed a relatively complex matrix or paradigm with the motion morphemes in the corpus of signs.

Note that the matrices in Tables 5 and 6 were roughly in complementary distribution. The motions that appeared infrequently in Table 5 (i.e., the Linear motion and the change-of-shape motions) were more likely to appear in Table 6 combined with OBJECT morphemes to describe intransitive events. Conversely, the motions that formed relatively complete matrices in Table 5 (the change-of-position motions and the no-change motions) were less frequently used with OBJECT handshapes to describe intransitive events in Table 6. Only the Long Arc motion seemed to be used both transitively with HAND morphemes (Table 5) and intransitively with OBJECT morphemes (Table 6). Apparently, David tended to use certain motion forms to represent transitive events and other motion forms to represent intransitive events.

Transitive meanings. As indicated above, OBJECT handshapes were combined not only with motions representing intransitive events but also with motions representing transitive events, i.e., events performed on a patient by an actor.[5] Table 7 presents examples of the OBJECT morphemes, including the Fist and the O, used in combination with the Short Arc motion. Note that in these signs, the handshape represents a characteristic of the patient and not of the actor. Thus, in contrast to the HAND morphemes used with transitive motions where attention is focused on the actor's manipulation of the patient, the OBJECT morphemes used with transitive motions focus attention on the patient alone. These combinations thus serve as a device to refocus attention.

As an example of the way David altered the form of his signs to refocus attention, David generated two distinct descriptions of the same event—a cowboy sipping on a straw. First, David held a O handshape (representing handling a small object, the straw) to his mouth,[6] a HAND morpheme that focused attention on the cowboy's hand actively manipulating the straw, as if to indicate "he holds the straw at mouth." In another representation of the same situation, David held a Point handshape (representing a thin, straight object, the straw) to his mouth, an OBJECT morpheme that brought attention to the straw alone, as if to indicate "the straw is held at mouth."

Table 7. Examples of OBJECT Handshapes Used in Combination with Transitive Repositioning Motions

	Fist	*O*	*C*	*Palm (animal or vehicle)*	*Point (Neutral)*
Short arc	Reposition a bulky object 2(3),[a] e.g., swing hammer head	Reposition a round compact object 2(3), e.g., put on hat	Reposition a curved object 1(2), e.g., place cowboy legs on horse	Reposition an animal or vehicle 2(2), e.g., put in bear	Reposition an object of any shape 3(3), e.g., turn over can of clay

[a]The first number represents the number of different types of events represented by the handshape/motion combination. The number in parentheses represents the total number of tokens. Only one-motion signs are included in the table.

David used OBJECT handshapes with five of the nine motion morphemes to represent transitive events. Table 8 presents the number of OBJECT morphemes used to represent the patient of a transitive action for each of the nine motions.[7] Note that the distribution of OBJECT morphemes with transitive motions (Table 8) appears very similar to the distribution of HAND morphemes with transitive motions (Table 5). In particular, there are no OBJECT morphemes combined with either Linear motions or change-of-shape motions. Thus, there appear to be

Table 8. Number of OBJECT Handshapes Used in Combination with Motions Representing Transitive Events[a]

	Number of Types (Tokens)[b]
Change of location	
Linear	—
Long arc	4(4)
Change of position	
Short arc	10(13)
Arc to and fro	1(1)
Circular	2(3)
Change of shape	
Open/close	—
Bend	—
Wiggle	—
No change	
No motion	3(5)

[a]Of the 26 signs in the table, 15 contained a Neutral Point handshape, thus focusing attention on the action itself rather than on the actor or patient.
[b]Only one-motion signs are included on the table.

restrictions on the types of motion forms David used to describe transitive events, independent of type of handshape (HAND or OBJECT). These restrictions may have been due to accidental discourse factors, e.g., David may not have had the opportunity to describe events in which an actor changed the shape of a patient or the shape of his hand on a patient. However, at least one of these restrictions (the absence of a transitive Linear motion) does not appear to be based on David's failure to describe a particular set of events. Note that David did describe events in which a change of location was performed transitively (i.e., events in which an actor acted on a patient to transfer it). However, when David described these events he tended to use the Long Arc motion (with either a HAND or an OBJECT handshape) and not the Linear motion. Thus, the restriction on a Linear motion form representing a transitive event may reflect a formal constraint within David's system.

Attribute meanings. David used four different OBJECT morphemes to represent attributes of static objects: the O (representing a round, compact object), the C (representing a curved object), the Palm (representing a flat, wide object), and the Palm (representing many particles). All of these OBJECT morphemes were used in combination with the No-motion morpheme. For example, the O morpheme was combined with the No-motion morpheme to describe a Christmas tree ball and a soap bubble; the C morpheme combined with the No-motion morpheme described an arced block; the Palm (Flat/Wide) morpheme combined with the No-motion morpheme described a flat puzzle-board; and the Palm (Many Particles) morpheme combined with the No-motion morpheme described a piece of train track with many spokes.

In sum, we found that the signs David produced during these sessions can be described in terms of frameworks or matrices of handshape and motion oppositions, i.e., handshape/motion paradigms. The meaning of each sign in the system thus appears to be based on a combination of the meanings of its parts—the handshape and motion morphemes.

Motions in Combination with Other Motions

Approximately 10% of David's signs contained two or more motions. All of the nine motion forms were produced in combination with other motions. In 32% (12/37) of these two-motion signs, the motions were produced sequentially (but without a break between the motions so that both appeared to be part of the same sign); in the other 68% (25/37), the two motions were produced simultaneously in a conflated motion.

The sequential two-motion signs typically described actions that occurred in sequence (12 signs). For example, David produced a Palm handshape (representing an animate object) combined first with a Long Arc motion (movement downward to an endpoint), then combined with a Short Arc motion (repositioning in place), and finally combined with a Linear motion (movement forward) to describe a penguin diving into the water, turning, and then going forward.

The simultaneous or conflated two-motion signs were used in three different ways: (1) The second motion represented the manner in which the first motion (always a change of location motion) was performed (10 signs). For example, David produced a Point handshape (representing a thin, straight object) combined simultaneously with a Wiggle motion (a quick to and fro movement) and a Linear motion (movement forward) to represent the way a straight and skinny dog nodded its head as it moved forward. (2) The second motion (always an open or close motion) represented the way an object was picked up before being moved (or released after being moved) (seven signs). For example, David produced a Fist handshape (representing handling a thin long object) with a Close motion (grasp) and a Short Arc motion (repositioning at the beginning of a change of location) to represent the way a long thin toybag was grasped in order that it be repositioned. Note that in signs of this type, the Close motion is performed simultaneously with the Short Arc motion—despite the fact that when the action is actually performed, the grasp motion precedes the repositioning motion. (3) The second motion (always a no change motion performed with the second hand) was used to establish the object on which the first motion was performed (eight signs). For example, one of David's hands formed a C (representing handling a large object) in combination with No Motion (hold) to represent holding a large, wind-up toy, while the other hand formed an O (representing handling a small object) in combination with a Circular motion (rotate) to represent rotating the knob of the wind-up toy.

Thus, just as the meaning of a simple one-motion sign in David's system can be described as the sum of the meanings of its hand and motion parts, so can the meaning of a complex two-motion sign in the system.

Summary of David's Morphological System

We have found that the corpus of signs David produced can be characterized as a system of handshape and motion morphemes; in particular, David's signs were composed of a limited and discrete set of five hand and nine motion forms each of which was consistently associated with a distinct meaning and recurred across different signs. Thus, David's signs appeared to be decomposable into smaller morpheme-like components, suggesting that his gesture system was indeed structured at the sign level.

David's signs did not always reflect referents in the real world as transparently as they might have. The signs were often more abstract and symbolic than a pantomime of a real world object or action would require and, as such, were not constrained by a tight fit between a sign and the object or action it represented. For example, despite the fact that in the manual modality one can, in principle, represent shapes and movements along a continuous dimension, David used discrete (not continuous) forms to represent objects and actions in his signs (e.g., he used the same handshape to represent holding a thin balloon string and a thicker steering wheel). When representing handling an object, David appeared

to choose among the limited number of handshapes available in his system, rather than shaping his hand to match precisely his actual handgrip on the object. At some level, David seemed to be sacrificing the fit between a sign and its referent to achieve categorical representation (e.g., David used a Fist handshape to represent holding a banana despite the fact that bananas require a wider handgrip). Thus, like ASL, David's gesture system does not take advantage of the possibility of continuous and transparent representation afforded by the manual modality and instead appears to be based on categorical representation, as are all conventional languages.

In addition, to be able to manipulate the focus of attention in a sentence, David would, at times, use a less transparent, less pantomimic representation than he possibly could have used. For example, when describing how one could put a cowboy on a horse, David could (and did) shape his hand as though he were holding the cowboy and placing it on the horse (i.e., a HAND handshape used with a transitive motion). However, at times, to describe the same event, David shaped his hand as though he were representing the cowboy's legs as they were placed around the horse (i.e., an OBJECT handshape used with the same transitive motion). This second sign is less like a pantomime than the first and serves to focus attention on the patient alone rather than on the actor and patient.

Comparisons between the Home Sign System and ASL Morphology

We have found that the corpus of signs David produced can be characterized as a system of handshape and motion morphemes, comparable in broad outline to the handshape and motion system that underlies ASL. Not surprisingly, however, the system of subsign components developed by David is not as complex as the morphological system underlying ASL, a conventional language with a rich linguistic history and shared by a wide community of signers.

Handshape Morphemes

The five predominant handshapes in David's system represent the unmarked handshapes of adult ASL systems (cf. Klima and Bellugi, 1979), and are the same handshapes produced by young deaf children learning ASL from their deaf parents during their initial states of acquisition (McIntire, 1977). Since David used only the unmarked and none of the marked handshapes of ASL, he used fewer handshapes overall than are found in ASL, even in the ASL produced by young children. Nevertheless, David's use of handshapes to represent objects parallels closely the way handshapes are used in ASL.

David's handshapes represented objects in three ways. First, a set of David's OBJECT handshapes represented the visual–geometric characteristics of an object: First (bulky object), O (round, compact object), C (curved object), Palm (flat, wide object), Palm (many small particles), and Point (thin, straight object).

In ASL, handshapes (called size and shape specifiers, cf. Supalla, 1982) are also used to represent the visual–geometric properties of an object, but the set of handshapes available in ASL is much larger than David's set. Moreover, the visual–geometric handshapes in ASL consist themselves of a group of simultaneous hand-part morphemes rather than a single handshape morpheme (Supalla, 1982). For example, the number of fingers extended represents the width or depth of an object (one finger = thin or flat, two fingers = narrow or shallow, four fingers = wide or deep) while the curvature of the palm represents the shape of an object (palm straight = straight object, palm curved = round object). These components are combined within a sign in ASL to represent the width/depth *and* shape of an object, e.g., one straight finger = thin and straight object and one curved finger = flat and round object. At present, we have no evidence to suggest that David's handshapes themselves consisted of a number of simultaneous morphemes rather than one single morpheme.

Second, David used one of his OBJECT handshapes to represent a semantic subcategory of objects: Palm (vehicle or animate object), i.e., a self-propelling object. In ASL, this same category is represented but with many more distinctions. For example, ASL has separate handshapes to represent a human vs. a small animal, and separate handshapes to represent a wheeled vehicle vs. an airplane vs. a boat (Supalla, 1982).

Finally, David's HAND handshapes represented an object indirectly by reflecting the handgrip used to manipulate the object: First (handle a small, long object), O (handle a small object), C (handle a large object), Palm (handle a large, flat surface), Palm (handle many small surfaces). Again, ASL has a set of handshapes that is used in comparable ways but with many more distinctions (e.g., thumb and finger touching, with the other three fingers extended and spread = handle a small or flatish object; flat palm with the thumb spread = handle a wide flattish bottomed object; flat palm with the fingers spread = handle a flat plane; McDonald, 1982).

Interestingly, when deaf children acquire ASL from their deaf parents, they tend at the earliest stages to use some handshapes comparable in form and meaning to David's. Supalla (1982) studied the development of size and shape and semantic classifiers in verbs of motion and location in three deaf children of deaf parents (ranging in age from 3;6 to 5;11). He found that all three of the children used what Supalla called "primitive" handshapes, the Palm and the Point. Two of the children used the Point for any category (as David did with his OBJECT Point = any object) while the third used the Point for wide, flat, and cylindrical objects. All three of the children used the Palm for animals, wheeled vehicles, and airplanes (as did David), and one used the Palm for wide, flat, and cylindrical objects as well. Thus, even when provided with a conventional language model, children tend to use the same simple forms for the same general categories as did David. However, it is important to point out that, even by age 3;6, the children in Supalla's study were correctly producing the more specified

handshapes for humans, animals, wheeled vehicles, and airplanes on a substantial number of the stimuli—handshapes and distinctions not seen in David's signs.

In sum, David's system of handshape morphemes resembles ASL in that handshapes are used to represent discrete classes of objects. Moreover, David's handshapes represent objects by capturing the same kinds of properties (size and shape, semantic category, handgrip) as are captured in the handshapes of ASL. Nevertheless, the structure of David's system of handshape morphemes is far less complex or intricate than the structure of handshape morphemes in ASL.

Motion Morphemes

David used nine motion forms in his signs, a set that is reminiscent of the set isolated by Newport (1981) and Supalla (1982) in their descriptions of motion in ASL. Moreover, the meanings of David's nine motion forms fall into the same four broad categories as do the motion meanings attributed to the signs of ASL, although the details of the motion meanings differ.

First, David used two forms (Linear and Long Arc) to represent change of location along *any* path. In ASL, the type of path is specified within the change of location morpheme: linear path means move along a straight path, arc path means move in an arc or jump (Supalla, 1982). Thus, the change of location morphemes in ASL are more specified than the comparable morphemes in David's system.

Second, David represented change of position with three forms, Short Arc (repositioning an object), Arc To and Fro (change position by moving back and forth), and Circular (move in a circular path or rotate). In ASL, two forms represent change of position or orientation: end-pivot means swing and mid-pivot means rotate (Supalla, 1982). A third ASL form, circular path, which means move in a circle, overlaps partially in meaning with David's Circular form but is listed as a change of location and not a change of orientation by Supalla.

Third, David used three forms to represent change of shape (Open/Close, Bend, and Wiggle). ASL has four forms that differ in detail from David's: spread, bend-flat, bend-round, and change-diameter, each of which reflects a change in the attributes of an object (Supalla, 1982).

Finally, David used his No-motion form to represent the existence of an object or holding an object in place. In ASL, a distinction is made between the existence and location of an object, and that distinction is conveyed through motion: a hold movement means existence and a minimal contacting movement means location (Supalla, 1982).

In addition, David's morphemic system resembles ASL in that it is combinatorial, i.e., motions can be combined with other motions. In both ASL (see Supalla, 1982) and David's system, motions combine with each other simultaneously or sequentially, and in either instance the meaning of a two-motion sign is the sum of the meanings of its motion parts.

The Role of the Child and His Environment in the Acquisition of Two Levels of Structure

Generating a Morphological System without a Conventional Language Model

Our analyses suggest that David developed a sign system that had morphological structure. In other words, when David generated a sign to refer to a particular object or action, the form of that sign was determined not only by the properties of the referent object or action, but also by how that sign fit with the other signs in David's lexicon. Thus, David's signs appeared to be created to fit into a framework, a system of contrasts. For example, David's motion form Long Arc, meaning change of location, contrasted with his motion form Short Arc, which meant change of position. Moreover, when the Long Arc was combined with a Fist (representing handling a small, long object), the meaning of the composite sign could be derived from the meanings of the individual motion and handshape forms (i.e., change the location of a small, long object) and differed systematically from the meaning of a Short Arc + Fist combination (which meant change the position of a small, long object).

The fact that David developed a morphological system without exposure to a conventional language model suggests that he might have been predisposed to develop a system of contrasts at the subsign level. David appeared to develop his lexicon by recruiting gestures from the actions of people and objects around him. We hypothesize that David first developed his lexical items by focusing only on the relationship between the form of the sign and the object or action it represented. Later (perhaps when he had accumulated a sufficient number of signs in his lexicon), David may have considered the form of one sign in relation to the form of other signs and may have regimented any regularities in his lexicon. For example, small, long objects tend to be held by a fist—not always, but perhaps often enough so that the Fist handshape might have predominated in the signs David created to represent handling small, long objects. David might then have made use of this trend in his lexicon and organized his system of contrasts around it.

If this hypothesis is correct, we would predict that David's lexicon ought to have changed over developmental time, simply because his early signs should have been created to conform only to sign–object constraints (i.e., the fit between the sign and the object or action it represents), while his later signs should have been created to conform to sign–sign constraints (the fit between a sign and the rest of the signs in the lexicon) as well as sign–object constraints. We would therefore expect it to be more difficult to describe David's early signs than his later signs in terms of a morphological system (i.e., there should be more "exceptions" in his early signs than his later signs, and perhaps different types of exceptions in his early signs than his later signs). Alternatively, we might expect "mismatches" between the signs David used and the objects and actions he represented with those signs in his later corpus after he had constructed a morphological system. Our future work will explore this prediction by analyzing the development of David's lexicon over time (Mylander and Goldin-Meadow, 1990).

In addition, this hypothesis implies that the details of David's morphological system depended not only on his propensity to impose an organization on his lexical items but also on the types of lexical items he created. We would therefore predict that if other deaf children inventing gesture systems without a conventional language model were to generate lexicons that differed substantially from David's lexicon in content and/or form, they might also generate morphological systems that differed from David's. In other words, the children might differ from David in the particular morphemes that comprised their systems but would not differ from him in having a morphological level. Our future work will explore this prediction by analyzing the lexicons of nine other deaf children who have invented gesture systems without exposure to a conventional language model.

The Resilience of Morphological Analysis

We have found that, even without the benefit of a conventional language model, a child can develop a communication system that has structure at the level of the word or sign, i.e., morphological structure. Thus, morphological structure appears to be a resilient property of language—a property that can be developed by a child despite a very impoverished language-learning environment. These findings support the hypothesis that children bring to language learning a predisposition for morphological analysis of a lexicon—either the conventional lexicon they are traditionally exposed to, or the lexicon they create on their own (see also Goldin-Meadow and Mylander, 1990a).

Evidence from other studies of language learning also argues for the resilience of morphological analysis in children. Children exposed to a spoken model of a conventional language that contains no morphology nevertheless tend to develop a morphological system in their own speech. For example, children who are exposed to pidgin languages that tend not to have morphology (i.e., structure within the world) have been found to creolize the language and in the process develop a system that has morphological structure (Kay and Sankoff, 1974; Sankoff and Laberge, 1973).

A second example of the resilience of morphological analysis comes from sign language. Deaf children are often born to deaf parents who learned ASL late in life, and some of these late-learning adults develop language systems that lack much of the morphological complexity of ASL (Newport, 1984). Nevertheless, the deaf children learning ASL from parents with incomplete morphological systems go on to develop sign systems with a complex morphological structure

indistinguishable from the morphological systems developed by deaf children learning ASL from parents with complete systems (Newport, 1984).

These observations from ASL, taken in conjunction with the data we report here, suggest that although some aspects of morphology will develop in the absence of any linguistic model, the type of linguistic input a child receives from his environment exerts significant influence on the *complexity* of the morphological system the child develops. The deaf child in our study lacked entirely the lexicon of conventional sign language, and constructed a system with far less complexity than the morphological system of ASL. Apparently, a child not exposed to a conventional language model is able to take only small steps toward developing a morphological system. In contrast, the literature shows that deaf children exposed to a model of ASL, even one with incomplete morphological structure, are able to develop the richly elaborated morphological system of ASL in all of its complexity (Newport, 1984).

The linguistic environment to which a child is exposed thus appears to play a role in the complexity of the morphological system the child induces. Nevertheless, the fact that David could fashion a morphological system—albeit a simple one—even without any conventional linguistic input suggests that some aspects of linguistic analysis are strongly guided by internal factors. At the very least, these data suggest that, with or without a language model, children seek structure at the morphological level as well as at the sentence level when developing a communication system (see also Goldin-Meadow and Mylander, 1990b).

In sum, our data support the notion that a child may be predisposed to impose structure at the word level, whatever input he receives. If a child is exposed to a conventional language model, he quite naturally learns the morphological structure in that model. However, even if a child is not exposed to a conventional language model, or is exposed to a conventional language model that lacks complete or extensive morphological analysis, the child still seems to impose morphological structure on the units that serve as words in his system.

We have found in our previous work that, even without the benefit of a conventional language model, a child can develop a communication system that has structure at the syntactic level, i.e., at the level of sentence-like units. We find here that this same communication system is also structured at the morphological level, at the level of word-like units. We suggest that hierarchical structure (or at least two hierarchical levels) appears to be a resilient property of language—a property whose development can withstand a dramatic alternation of the learning conditions children typically experience when acquiring language. Moreover, the fact that a deaf child can develop a hierarchically structured communication system even when he has no explicit model for such a system suggests that the human brain is strongly canalized to produce linguistic systems with hierarchical organization. In this respect, the human brain differs greatly from the brains of great apes who, even when reared under similar conditions, do not spontaneously invent organized linguistic systems.

Notes

1. Characterizing signs are represented in capitalized letters, e.g., "EAT" represents a jabbing motion toward the mouth.
2. The term "patient" refers to objects that are affected by the actions of an actor (i.e., the object of a transitive event).
3. Two of the types of characterizing signs David produced during these videotapes are omitted from the analyses presented here and will be described in a forthcoming report: (1) 243 signs which were conventional in that they occur in the spontaneous gestures accompanying the speech of hearing adults and children in our culture (e.g., a flat hand extended palm-up to mean "give," or two fists held together and then rotated away from each other to mean "broken"), and (2) 68 signs in which the motion of the sign traces the extent or outline of an object.
4. Numbers reported for handshape (Table 2) reflect signs in which handshape was codable regardless of whether the corresponding motion could be seen and coded. Similarly, numbers reported for motion (Table 4) reflect signs in which motion was codable, again independent of whether the corresponding handshape could be coded. Numbers reported for handshape and motion combinations (Table 5 and 6) reflect signs in which both handshape and motion were codable and neither handshape nor motion was an exception (i.e., could not be classified according to the form/meaning pairings described in Tables 2 and 4).
5. We use the term "actor" to refer to the doer in a transitive event rather than the term "agent" traditionally used in linguistic descriptions.
6. In addition to handshape and motion, we also coded information relevant to a possible third morpheme—place of articulation (i.e., the location where each sign was produced). These data are not analyzed here and will be described in a forthcoming report.
7. Of the 26 signs listed in Table 8, 15 contained a Neutral Point handshape. The Neutral Point does not actually capture characteristics of either the actor or the patient. Thus, for these signs, the focus of attention may have been on the action itself.

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