

The role of parental input in the development of a morphological system*

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ABSTRACT

In order to isolate the properties of language whose development can withstand wide variations in learning conditions, we have observed children who have not had access to any conventional linguistic input but who have otherwise experienced normal social environments. The children we study are deaf with hearing losses so severe that they cannot naturally acquire spoken language, and whose hearing parents have chosen not to expose them to a sign language. In previous work, we demonstrated that, despite their lack of conventional linguistic input, the children developed spontaneous gesture systems which were structured at the level of the sentence, with regularities identifiable across gestures in a sentence, akin to syntactic structure. The present study was undertaken to determine whether one of these deaf children's gesture systems was structured at a second level, the level of the gesture - that is, were there regularities WITHIN a gesture, akin to morphologic structure?

We have found that (1) the deaf child's gestures could be characterized by a paradigm of handshape and motion combinations which formed a matrix for virtually all of his spontaneous gestures, and (2) the deaf child's gesture system was considerably more complex than the model provided by his hearing mother. These data emphasize the child's contribution to structural regularity at the intra-word level, and suggest that such structure is a resilient property of language.

INTRODUCTION

Resilience and fragility in language development

Language is mastered by children experiencing a wide range of environments and thus can be considered a generally robust phenomenon (cf. Wimsatt,

1981). Despite great variability among cultures in the patterns of child-caregiver communications (e.g. Schieffelin, 1979; Miller, 1982; Ochs, 1982; Pye, 1986), virtually all children in all cultures master the language to which they are exposed (Slobin, 1985).

However, there do appear to be limits on the robustness of language development in children. Children who have been brought up by animals have not been found to develop any human language spontaneously (Brown, 1958; Lane, 1977), nor have children reared by humans under inhumane conditions (Davis, 1940; Mason, 1942; Curtiss, 1977). For example, Curtiss studied a girl who had been confined to a small room with no freedom of movement and no human companionship for the first 13 years of her life. During this period of unusual deprivation, language did not develop at all, providing evidence for at least one (albeit extreme) limitation on the resilience of language development in children.

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, Bard & Johnson (1981) 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.¹

In our work, we have focused on isolating those properties of language whose development CAN withstand wide variations in learning conditions - properties which we have called the 'resilient' properties of language (as opposed to those properties which appear more sensitive to the linguistic environment - the 'fragile' properties of language). In an attempt to determine which properties of language can be developed by a child under one set of severely degraded input conditions, we have observed children who have not had access to any conventional linguistic input but who have otherwise experienced normal social environments. The children we study are deaf with hearing losses so severe that they cannot naturally acquire spoken language. In addition, these children are born to hearing parents who

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[1] It is important to note that the child studied by Sachs *et al.* (1981) was unusual in his extreme lack of exposure to oral language. Hearing children of deaf parents are typically encouraged to be in situations where they will experience oral language and, even if this exposure is less than the norm, they tend to acquire spoken language at a normal pace (Schiff, 1979). The point we wish to stress here is that, even though the child in Sachs' study experienced a radically atypical language-learning environment, some properties of language WERE found in his speech and thus appeared to be unaffected by the child's impoverished environment.

have chosen not to expose them to a sign language. We have found that these deaf children, despite their impoverished language learning conditions, develop gestural communication systems which are structured in many ways like the communication systems of young children learning language in ordinary linguistic environments, both hearing children learning spoken language from their hearing parents and deaf children learning (conventional) sign language from their deaf parents.

In particular, we have demonstrated that each of ten deaf subjects combined their gestures into strings that functioned in a number of respects like the sentences of early child language; these strings were consequently labelled 'gesture sentences'. First, the children's gesture sentences expressed the semantic relations (in particular, action and attribute relations) typically found in early child language (Goldin-Meadow & Mylander, 1984). Secondly, the predicates in the deaf children's sentences were comparable to the predicates of early child language in that they were composed of underlying frames or structures with one, two, or three arguments (e.g. all of the children produced 'transfer' or 'give' gestures with an inferred predicate structure containing three arguments – the actor, patient, and recipient, as in 'you/sister give duck to her/Susan' (Feldman, Goldin-Meadow & Gleitman, 1978). Thirdly, the gesture sentences produced by the deaf children were structured on the surface as are the sentences of early child language in that they conformed to regularities of two types: ordering regularities and production probability regularities (Goldin-Meadow & Feldman, 1975, 1977). Finally, the deaf children generated novel, complex gesture sentences containing at least two propositions beginning around 2;2, an age comparable to the onset of complex sentences in children learning conventional languages (Goldin-Meadow, 1982, 1987).

Thus, each of the deaf children had developed a gesture system with structure at the level of the sentence, that is, with structure identifiable across gestures in a string, akin to syntactic structure. We propose in this study to consider structure in the deaf child's gesture system at a second level – at the level of the gesture, that is, structure within a gesture, akin to morphologic structure.

Children acquiring either a conventional spoken language or a conventional sign language begin to develop structure at the level of the word or sign by their fourth year. As a rule, children begin with an initial period during which they learn the words or signs of their language as unanalysed wholes or 'amalgams' (MacWhinney, 1978; Newport, 1982). During the next period, they begin to learn that a word or sign can be composed of parts (or morphemes), each of which is meaningful. For example, initially a child might use the word *untie* appropriately but not be aware that the word is composed of two parts, *un* and *tie*. Later, however, the child learns that *un* is a separable piece of the word associated with a particular meaning (i.e. to

undo the result of an action), an insight reflected in the child's overgeneralized uses of *un* (e.g. *unclothes* = to take the clothes off a baby, Bowerman, 1982). At this stage, the child gains productive control over the parts of words, knowing the parts themselves and how they combine to form words, and thus has structure not only at the level of the sentence but also at the level of the words.

If a hierarchy of structured levels is common to natural child language and if we wish to explore fully the aspects of linguistic systems which are sufficiently resilient to withstand severe environmental deprivation, it becomes important to ask whether the deaf children in our studies also develop such hierarchical structure in their gestural communications. In other words, we explore whether there is intra-gesture structure as well as inter-gesture structure in the gestures of the deaf children, and thus whether hierarchical structure itself as a 'resilient' property of language.

The deaf children in our studies had not been exposed to an accessible conventional language model. They therefore could not have based their structured gesture systems on such a conventional model. However, we recognize that the children were not developing their gestures in a vacuum, but rather were growing up in a world of hearing individuals who are noted to gesture frequently along with their speech (cf. Shatz, 1982; Perry, Church & Goldin-Meadow, 1988; Bekken, 1989). In our previous work on sentence-level structure, we found that several aspects of the deaf children's gesture systems had quite obvious ties to the gestures produced by their hearing mothers. Both the children and their mothers produced pointing gestures and iconic gestures, and both combined those gestures into linear strings. However, the mothers' gesture strings did not show the same structural regularities as their children's. In particular, the mothers showed no reliable gesture order patterns in their strings, and the production probability patterns in the mothers' gesture strings were different from the production probability patterns in their children's strings. Moreover, the mothers began conveying two propositions in their gesture strings later in the study than their children, and produced proportionately fewer sentences with conjoined propositions than their children (Goldin-Meadow & Mylander, 1983, 1984). Thus, the children's gestures had surpassed the models provided by their mothers' gestures in having structure at the sentence level.

In the present work, we extend our analysis of the role (or non-role) of parental input in the development of the deaf child's gesture system. We explore whether the spontaneous gestures produced by the deaf child's hearing mother are structured at the level of the gesture and, if so, whether this structure might serve as a model for intra-gesture structure in the deaf child's gestures.

In sum, our objectives are twofold: (1) to determine whether the gestural communication of a deaf child without access to a conventional language

model can be structured at the level of the gesture; that is, can the child develop a morphology for his gestures (Study 1)? and (2) to determine which aspects of this morphologic structure (if any) can be attributed to the gestures produced by the deaf child's mother (Study 2).

Background on deafness and language learning

The sign languages of the deaf are autonomous languages which are not based on the spoken languages of hearing cultures (Bellugi & Studdert-Kennedy, 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 (e.g. Liddell, 1980), morphological (e.g. Klima & Bellugi, 1979) and 'phonological' (e.g. Padden & Perlmutter, 1987) 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 (Newport & Meier, 1985). 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 & 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 five or six, and despite intensive early training programmes, the average profoundly deaf child has only a very reduced oral linguistic capacity (Meadow, 1961; Conrad, 1979).

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 inopportune circumstances, these deaf children might be expected to fail to communicate at all, or perhaps to communicate only in non-symbolic 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 (Tervoort, 1961; Fant,

1972; Moores, 1974). These gestures are conventionally referred to as 'home sign'. Early studies, however, did not ask whether home sign systems are structured as human languages are. In contrast, our work focuses particularly on the structural aspects of deaf children's home sign systems.

Our previous work has focused on structural properties at the level of the sentence in the deaf children's gestures. The present study focuses 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.

Structure at the level of the sign in American Sign Language

ASL morphology. Research on morphology in ASL (see Wilbur, 1987 for a general review) has focused on inflectional morphology for marking aspect and distribution on verbs and pluralization on nouns (Fischer & Gough, 1978; Klima & Bellugi, 1979) and on derivational morphology which distinguishes verb stems from related noun stems (Supalla & Newport, 1978). The research has shown that (like spoken language morphology) stems in ASL undergo a variety of inflectional processes that apply in an ordered and recursive fashion.

Moreover, recent research has found ASL to be comparable to those spoken languages that are morphologically quite complex. This work has focused on signs that are highly mimetic in form (as contrasted with the 'frozen' signs of ASL that are listed in ASL dictionaries as single-morpheme stems). Mimetic signs in ASL were originally thought to be built on an analog use of movement and space in which movement is mapped in a continuous rather than a discrete fashion (DeMatteo, 1977; Cohen, Namir & Schlesinger, 1977). In other words, mimetic signs were thought not to be divisible into component parts, but rather were considered unanalysable lexical items that mapped, as wholes, onto events in the world. However, recent research has shown these mimetic signs to be composed of combinations of a limited set of discrete morphemes (Newport, 1981; McDonald, 1982; Schick, 1987). 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 signs 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.

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 (Supalla, 1982), 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 = a human; 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, 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) can be combined with 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, a vehicle jumps forward). Thus, many of the signs of ASL can be described in terms of a combination of handshape and motion morphemes that together form paradigmatic sets.

Acquisition of ASL morphology. The earliest signs produced by deaf children acquiring ASL from their deaf parents (referred to as '2nd-generation deaf') are lexical items that are uninflected citation forms (Ellenberger & Steyaert, 1978; Meier, 1981). These signs are either frozen signs (stems with no internal stem morphology and no derivational morphology) or signs which, although morphologically complex forms for the adult, are unanalysed amalgams for the child (Newport, 1981). At around age 2;6, deaf children learning ASL begin to acquire discrete morphemes one at a time, and (as in the hearing child's acquisition of morphologically complex spoken languages) morpheme acquisition continues in the deaf child until at least age 6;0 (Kantor, 1980; Supalla, 1982; Schick, 1986).

As mentioned previously, 90% of deaf children are born to hearing parents and thus are unlikely to be exposed to ASL from birth. In fact, many of these '1st-generation' deaf children are not exposed to ASL for the first time until adolescence or adulthood. Unlike the 2nd-generation deaf who learn ASL from birth and show complete mastery of ASL morphology when tested as adults, 1st-generation deaf have been found to have only partial control of ASL morphology as adults – even if they have used ASL as their primary language for 40–50 years (Newport, 1984). This finding highlights two points about the acquisition of morphology: (1) Morphology-learning appears to be sensitive to age of acquisition, with mastery of the system associated with early (native) acquisition. (2) Since 2nd-generation deaf children (who master ASL morphology completely) often receive their linguistic input from their 1st-generation deaf parents who have NOT fully mastered the system, morphology development during the early years appears to be relatively insensitive to the nature of input (Singleton & Newport, 1987).

These observations highlight the potential resilience of early morphology development and lead us to ask: How impoverished can linguistic input be

and still allow a child to develop a morphological system? Data from our deaf subjects allow us to address this question in an extreme form. We ask whether a child lacking any conventional linguistic input can still develop a morphological system. Study 1 addresses this question.

STUDY 1: THE DEVELOPMENT OF A MORPHOLOGICAL SYSTEM WITHOUT A CONVENTIONAL LANGUAGE MODEL

METHOD

Subject. To determine whether the gestures of the deaf subjects in our studies can be characterized by systematic combinations of meaningful forms, we selected one of our original subjects (David) and analysed the mimetic gestures (characterizing gestures in our terminology) 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. These ages span the age range during which both deaf (Supalla, 1982) and hearing (MacWhinney, 1976) children learning conventional languages have already begun to acquire certain morphemic distinctions. Two types of characterizing gestures were omitted from these analyses: (1) 243 'conventional' gestures which occur routinely in the spontaneous gestures of hearing adults and children in our culture (e.g. a flat hand extended palm-up to mean 'give'), and (2) 68 gestures in which the motion traces the extent of an object.

At the time of our observations, David had made little progress in oral language, occasionally producing single words and never combining those words into sentences. Although we did not test David's comprehension of spoken English, his parents reported that it was extremely limited at this point in development and did not improve dramatically when he wore his hearing aids.

It is, of course, possible that David was able to use whatever information he could glean from the speech signal to help construct word-level structure in his gesture system. However, in our previous work, we found little evidence to suggest that the deaf children in our studies were actually attending to the speech their mothers produced and little evidence to suggest that the structural information available in speech had been incorporated into the deaf children's gesture sentences (Goldin-Meadow & Mylander, 1984). In addition, at the time of our observations David had not been exposed to a conventional sign language, either American Sign Language or any of the varieties of Signed English. David was attending an oral pre-school in Philadelphia. His teachers knew no sign language, nor did any of the children in his class, and exposure to other children in the school was limited since David's class did not take recess with the older children in the school.

Coding and analysis. In our analyses, to qualify as a characterizing gesture, an act must satisfy two criteria: (1) the act must be directed to another individual (i.e. it must be communicative), and (2) the act must not be a direct manipulation of a relevant object or person (i.e. it must be 'empty-handed': see Goldin-Meadow & Mylander, 1984: 17 for additional discussion). It is worth noting that these two criteria are often not invoked for an act to be considered a gesture in studies of hearing children (cf. Volterra, Bates, Benigni, Bretherton & Camaioni, 1979; Bates, Bretherton, Shore & McNew, 1983). If gestures ARE required to be both communicative and empty-handed, characterizing gestures are rarely noted to accompany hearing children's speech (Petitto, 1988). Moreover, even though certain hearing children are particularly prone to gestural communication (Volterra, 1981; Acredolo & Goodwyn, 1985), it is unlikely that these children use gesture as extensively as the deaf children in our studies for whom gesture is the primary means of communication.

The videotapes of David were coded initially at the sentence level according to a system described in detail in Goldin-Meadow (1979). We glossed all characterizing gestures as predicates, assigning act predicate meanings to gestures that mirrored the actions on or by objects (e.g. EAT) and assigning attribute predicate meanings to gestures that mirrored the perceptual characteristics of objects (e.g. ROUND; see Goldin-Meadow & Mylander, 1984: 23-6, for the rationale behind these coding decisions). For the present analysis, we code the meaning of each gesture twice: (1) We first code the gesture in terms of the characteristics of the OBJECT that the gesture is used to refer to (either the object involved in the actions of act predicates, or the object described in attribute predicates). We take this object information to be relevant to the meaning of handshape forms (cf. Table 2 below). (2) We also code the gesture in terms of the characteristics of the ACTION that the gesture is used to refer to, and we take this information to be relevant to the meaning of motion forms (cf. Table 4 below). Reliability between two independent coders ranged from 85 to 95% agreement for coding handshape and from 83 to 93% agreement for coding motion.

Coding handshape forms and meanings. 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. We coded handshapes continuously along each dimension without establishing *a priori* either discrete categories or boundaries. Thus, for example, we wrote down the estimated 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.

To determine the meaning of each handshape form, we first listed all of the

objects represented by each handshape form used in the 1-motion gestures (gestures containing only a single motion) that 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 shared 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.

In principle, it is possible to establish form/meaning pairings by reversing this procedure, that is, to begin with meaning by grouping all objects with a particular characteristic (e.g. all objects that are curved) and then to determine form by asking whether those objects are represented by the same handshape. However, it is difficult, if not impossible, to classify objects *a priori* using this system. For example, a turtle could be considered a curved object, an animate object, or a wide object depending upon the aspect of the turtle that the child is focusing on. Moreover, there is no obvious reason to expect the child to use the same handshape for the turtle as curved object, for the turtle as animate object, and for the turtle as wide object. By beginning our search for form/meaning pairings with handshape FORM, we are allowing the child's behaviour to guide us in categorizing objects. Thus, the turtle would be considered a curved object when the classification by handshape form places it among a group of objects that are curved, an animate object when the classification by form places it among a group of objects that are animate, etc. In this respect, David's system may be comparable to ASL (and, for that matter, all classifier systems; see Craig, 1985) where a given referent can be represented by a variety of classifier handshapes depending upon the saliency of certain perceptual and functional features (see Wilbur, Bernstein & Kantor, 1985). It is worth noting that, in their exploration of how to best characterize a set of semantic classifiers in ASL, Wilbur *et al.* (1985) also began with form rather than meaning (i.e. they presented their subjects with a particular handshape form and asked which objects could be represented by that form, rather than presenting the subjects with an object and asking which forms could be used to represent that object).

Coding motion forms and meanings. Motions were coded 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 vs. > 7 inches) and directionality (unidirectional vs. bidirectional).

To determine whether each of David's nine motion forms was associated with a particular class of meanings, we listed all of the actions David represented with each of the nine motion forms in the 1-motion gestures 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.

RESULTS

Handshape morphemes

Handshape forms. We found that David used only a restricted number of values on each of the four dimensions we coded (i.e. shape of the palm, distance between the fingers and the thumb, number of fingers extended, and presence or absence of spread between the fingers). 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 464 (98%) of all of the handshapes David produced ($N = 473$).

TABLE 1. *Description of David's handshape forms*

Handshape form	Description
FIST O	Fingers and thumb curled into palm Index finger or 4 fingers bent toward thumb with 1/2 inch or less between the thumb and finger(s)*
C	Index finger or 4 fingers bent toward thumb with 3 inches between the thumb and finger(s)*
PALM POINT	4 fingers extended Index finger extended

* If only the index finger was bent toward the thumb in the O and C handshapes, the other 3 fingers were either curled into the palm or held sloppily in an untensed manner.

Handshape form/meaning mapping. We next asked 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 (these two types of handshapes are reminiscent of handle classifiers and of semantic or size- and shape classifiers, respectively, in ASL; see McDonald, 1982; Schick, 1987). For example, to describe a picture of a knife, David produced a Fist handshape (with a back and forth movement) which mirrors a cutter's hand manipulating a knife, and thus is an instance of a HAND handshape. In contrast, to describe the knife in a separate sentence, David produced a Palm handshape held perpendicular to the table (with the same back and forth movement), mirroring the flat shape of the knife blade 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 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].

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. We found that 368 (95%) of the 387 handshapes David produced in his 1-motion gestures 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 2-motion gestures (gestures that contained two motions concatenated without a break so that both appeared to be within the same gesture) were also found to conform to the form/meaning categories established on the basis of the 1-motion gestures produced during the 3;11 session. 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 which 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) which were represented by a C hand. 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 gestures (Table 3). The motion forms displayed in Table 3 account for 100% of the gestures David produced during these sessions ($N = 514$).

TABLE 2. *Meanings of David's handshape forms*^a

Form	HAND morphemes		OBJECT morphemes	
	Meaning	Types (tokens)	Meaning	Types (tokens)
FIST	Handle small, long object (e.g. spoon, drumstick, balloon string, handlebar) ^b	19 (70)	Bulky object (e.g. hammer head)	2 (3)
O	Handle small object (e.g. crank, shoe lace) ^b	31 (102)	Round compact object (e.g. round hat, ice 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. fish, flag, bird wings)	9 (43)
POINT	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)
			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 gestures during the seven videotaped sessions. The numbers reflect gestures in which handshape was codable regardless of whether the corresponding motion could be seen and coded. 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 in diameter; long = > 5 inches in length.

TABLE 3. *Description of David's motion forms*

Motion form	Description
LINEAR	Hand moves in a straight path
LONG ARC	Hand moves unidirectionally in an arced path > 7 inches in length ^a
SHORT ARC	Hand moves unidirectionally in an arced path < 7 inches in length
ARC TO & FRO	Hand moves bidirectionally in an arced path of any length
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

^a The cut-off for length of the path of an arc was established at 7 inches by first categorizing arcs into long arcs (> 10 inches), short arcs (< 5 inches), and intermediate arcs (> 5 and < 10 inches). We found that the long arcs were used primarily to represent change of location along a path, while the short arcs were used to represent change of position in place; since the intermediate arcs were used for both types of motions, we arbitrarily established the cut-off between short and long arcs in the middle of the intermediate category (7 inches). Reliability for coding length of arcs was 90% agreement between two coders ($N = 42$).

Motion form/meaning mapping. Table 4 presents the meanings of the motion forms David produced in his 1-motion gestures 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: (1) the Linear and Long Arc forms represented CHANGE OF LOCATION along a path, either of an object (or person) moving on its own (e.g. bubble go up, we go down), or an object being moved by a person (e.g. move coat, move spoon to mouth); (2) the Arc To & Fro, Circular, and Short Arc forms represented CHANGE OF POSITION either of an object (or person) repositioning itself (e.g. wheel tip-over), or an object being repositioned by a person (e.g. turn-over clay); (3) the Open/Close, Bend, and Wiggle forms represented CHANGE OF SHAPE either of an object altering its own form (e.g. bubble expands, fish bends [to swim]), or a hand altering its shape on an object (e.g. hand closes [around toy bulb], fingers wiggle [to strike piano keys]); and (4) the No-Motion form represented 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 39% (90%) of the 439 motions in the 1-motion gestures David produced during the seven videotaped sessions could be classified

TABLE 4. *Meanings of David's motion forms^a*

Type of motion	Form	Meaning	Types (tokens)
CHANGE OF LOCATION	Linear	Change of location by moving along a path (e.g. bubble goes upward)	16 (34)
	Long Arc	Change of location by moving along a path, typically to or from a particular endpoint (e.g. penny arcs forward to bank)	19 (24)
CHANGE OF POSITION	Arc To & Fro	Reposition by moving back and forth (e.g. wings flap)	29 (114)
	Circular	Reposition by moving in a circle or rotating around an axis (e.g. wheel rotates)	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 (e.g. wheel tips-over)	33 (71)
CHANGE OF SHAPE	Open/Close	Open/close, expand/contract, or flicker on/off (e.g. claw closes)	9 (16)
	Bend	Bend at joint (e.g. fish bends to swim)	2 (5)
	Wiggle	Wiggle back and forth (e.g. snow flutters)	2 (3)
NO CHANGE	No Motion	Hold in place or exist ^b (e.g. hold bubble-wand at mouth; bubble exists)	29 (91)

^a The table contains the motions found in David's one-motion gestures during the seven videotaped sessions. The numbers reflect gestures in which motion was codable regardless of whether the corresponding handshape could be seen and coded. 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.

^b All attribute signs were, by definition, produced without motion. We arbitrarily assigned the meaning 'exists' or 'is' as a placeholder for the no-motion component of these gestures in the analysis in this table. The absence of motion in attribute gestures may, of course, be meaningless. If so, the attribute gestures should be glossed only in terms of the object characteristics they portrayed (e.g. ROUND, CURVED, BULKY), and should be included only in Table 2 (handshape meanings) and not in this table (motion meanings).

according to the form/meaning pairings listed in Table 4. In addition, 69 (92%) of the 75 motions in David's 2-motion gestures conformed to the form/meaning pairings established on the basis of the 1-motion gestures 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; the Short Arc form in David's system represents repositioning in place and would have been appropriate had David been describing a turtle flipping over in one spot), or a Long Arc form used to represent an object being repositioned (e.g. swinging a hammer; the Long Arc form in David's system represents relocating from one point to another and would have been appropriate had David been describing moving the hammer from place 1 to place 2).

Handshape and motion combinations

We have shown that David's gestures 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 gestures themselves were in fact composites of handshape and motion morphemes, i.e. that handshape and motion are separable units, rather than one unanalysed whole. Since gestures 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 that a handshape is not uniquely associated with one motion but rather is combined with several different motions in different gestures, 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 gestures, we infer evidence for the separability of that motion.

The distribution of HAND and OBJECT handshape morphemes with the nine motion morphemes is shown in Table 5. Empty cells in the table represent handshape/motion combinations that David did not use at all during these sessions. The numbers in Table 5 represent the number of different types of events represented by each pairing of a 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 1-motion gestures, excluding those which were exceptions to either Table 2 (handshape form/meaning pairings) or Table 4 (motion form/meaning pairings).

Note that most of David's handshape morphemes could be found in combination with more than one motion morpheme, and vice versa. As a result, David's gestures can be said to conform to a framework or system of contrasts. As an example from David's HAND handshapes of how the morphemes of David's gestures systematically contrasted with one another, the CHAND handshape was used in combination with the Short Arc motion to mean 'change the position of a large object by hand' (e.g. pick-up bubble jar). The same Short Arc motion when used in combination with a different

TABLE 5. David's handshape/motion combinations^{a, b}

Handshapes	Motions										No change	
	Change of location			Change of position			Change of shape					
	Linear Path	Long Arc	Short Arc	Arc To & Fro	Circular	Open/Close	Bend	Wiggle	No Motion			
HAND handshapes												
Fist	—	1 (1)	6 (12)	7 (28)	1 (1)	1 (1)	1 (1)	—	—	—	6 (16)	
O	—	1 (1)	10 (20)	7 (42)	5 (8)	—	—	—	—	—	9 (24)	
C	—	—	2 (2)	1 (1)	4 (10)	—	—	—	—	—	3 (6)	
Palm	1 (1)	1 (2)	2 (5)	5 (8)	—	—	—	—	1 (2)	—	—	
Large surface	—	—	—	1 (1)	—	—	—	—	—	—	—	
Many surfaces	—	—	—	—	—	—	—	—	—	—	—	
OBJECT handshapes												
Fist	—	—	2 (3)	—	—	—	—	—	—	—	—	
O	—	—	2 (3)	1 (1)	—	—	—	—	—	—	6 (11)	
C	2 (3)	1 (1)	1 (2)	—	—	—	—	—	—	—	1 (1)	
Palm	1 (1)	1 (1)	1 (1)	5 (18)	—	—	—	—	—	—	4 (18)	
Flat-wide	9 (13)	4 (4)	4 (4)	—	—	—	—	—	—	—	—	
Animate-vehicle	—	1 (1)	1 (1)	—	—	—	—	—	—	—	—	
Particles	—	—	—	—	—	—	—	—	—	—	—	
Point	—	—	—	—	—	—	—	—	—	—	—	
Straight-skinny	1 (2)	2 (2)	—	—	—	—	—	—	—	—	—	
Neutral	3 (7)	5 (7)	3 (3)	—	2 (3)	—	—	—	—	—	—	

^a The first number in each entry represents the number of different types of events represented by the handshape/motion combination. The number in parentheses represents the total number of times the handshape/motion combination was used, i.e. the number of TOKENS. Only gestures in which both handshape and motion were codable are included in the table. The HAND Point morpheme (meaning handle a small surface) is not included in the table since it did not occur with any well-formed motions.

^b Only one-motion gestures are included in this table, i.e. the table does not include gestures in which motions were combined with other motions. e.g. David wiggled his finger (wiggle motion) as he moved the finger forward in a straight path (linear motion); this two-motion gesture was used to represent a thumb dog shaking its head back and forth as it moved forward. Approximately 10% of the gestures David produced during these seven sessions contained two or more motions. These two-motion gestures are described in detail in Goldin-Meadow & Mylander, 1990.

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 & Fro) meant 'move a small, long object to and fro by hand' (e.g. wave balloon string back and forth).

As an example from David's OBJECT handshapes, the C OBJECT 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. sister sits). The handshape morphemes in David's gestures thus formed a matrix or paradigm (albeit incomplete) with the motion morphemes in the corpus of gestures.

The development of the morphological system

The next analysis explores the developmental steps that David might have taken in arriving at this handshape/motion system of contrasts. We hypothesize that David first developed his lexical items by focusing only on the relationship between the form of his gesture and the event it represented. Later, perhaps when he had accumulated a sufficient number of gestures in his lexicon, David may have begun to consider his gestures in relation to one another and may have organized his gestures around any regularities that appeared in his lexicon. For example, small, long objects tend to be held by a fist—not always, but perhaps often enough so that fist-like handshapes might have predominated in the gestures 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 expect that, early on, each gesture in David's repertoire might represent a single referent rather than a class of referents. For example, David might use the C handshape in combination with a Circular motion to refer only to twisting a bubble jar lid, and the C handshape in combination with a Short Arc motion to refer only to repositioning a cup. After initially generating each gesture in his system to map onto a particular event as a whole, David might later 'analyse' his set of wholes into handshape and motion components which map onto classes of objects and actions, respectively. We would then expect that the C-hand+Circular combination, for example, would not only be used to mean 'twist the bubble jar lid' but also to mean 'rotate the large knob' or 'move the large toy in a circle'; that is, the C handshape in this and in other gestures would be used to refer to a class of objects (objects with large diameters that can be grasped by hand) and the Circular motion in this and in other gestures

would be used to refer to a class of actions (rotating or moving objects around a centre point). If David were to follow this developmental path, we would expect that the handshape/motion combinations in David's later sessions would be used to represent classes of related events rather than individual events.

Table 6 presents the number of different types of handshape/motion combinations David used to refer to an individual event vs. a class of events for each of the seven sessions. Note that David used eight different types of handshape/motion combinations during the first session (age 2;10). However, each of those eight combinations was used to describe only one event; for example, he used the C-hand combined with a Circular motion to refer exclusively to twisting open a jar. It was not until the second session (age 2;11) that David first used a particular handshape/motion combination to refer to more than one event; that is, the C-hand+Circular motion combination would be used to refer to a variety of related events - opening a jar, rotating a wide knob, moving a train in a circle, etc. The number of handshape/motion combinations referring to a class of events (as opposed to an individual event) subsequently increased to 10 or more by age 3;11. It is important to note that the onset of handshape/motion combinations which refer to classes of events as opposed to individual events could NOT be attributed to a general increase in the total number of gestures David produced - David produced approximately the same number of characterizing gestures during the first session (25 gestures at age 2;10) as he did during the second and fourth sessions (20 gestures at age 2;11 and 30 gestures at age 3;3). Thus, when first generating gestures, David appeared to create each gesture to map, as a whole, onto an individual event. Only later

TABLE 6. *David's use of gestures to refer to an individual event vs. a class of events^a*

Age	Number of different types of handshape/motion combinations	
	Referring to an individual event	Referring to a class of events
2;10	8	0
2;11	6	1
3;0	2	0
3;3	11	4
3;5	9	5
3;11	27	15
4;10	16	10

^a The numbers at each age represent the total number of different types of handshape/motion combinations David used, classified according to whether each combination was used to refer to an individual event vs. a class of events.

did David appear to 'analyse' his set of wholes into handshape and motion components which mapped onto classes of objects and actions, respectively. The developmental pattern seen in Table 6 is consistent with the hypothesis that David's gestures were initially unanalysed wholes that were later organized in relation to one another to form a system of contrasts.

DISCUSSION

We have found that the gestures David produced during the two-year period under study formed a system with structural regularities. To assess how 'language-like' this structure was, we compared David's gestures to conventional languages in the same manual modality. We found that the system of handshape and motion morphemes developed by David is comparable in broad outline to the handshape and motion systems that underlie conventional sign languages such as ASL. Not surprisingly, however, the system of subgesture components developed by David is not as complex as the morphological system underlying ASL, a language with a rich linguistic history and shared by a wide community of signers.

Handshape and motion forms

The handshape and motion forms found in David's gestures are also found in ASL. In fact, the five handshape forms in David's gestures are among the most frequent in ASL (cf. Klima & Bellugi, 1979) and are the unmarked forms in ASL (i.e. they comprise the set of handshapes that can appear in the subordinate hand of a two-handed sign, Battison, 1978). These handshapes are also among the first to be acquired by deaf children acquiring ASL from their deaf parents (McIntire, 1977). In addition, the nine motion forms in David's gestures are comparable to the set used by Newport (1981) and Supalla (1982) to describe motion in ASL.

Moreover, the handshape and motion forms found in David's gestures are not limited to conventional manual communication systems found only in the United States. For example, Kendon (1987) has identified these same handshape and motion forms in the sign languages of seven central Australian Aboriginal groups. These sign languages were developed by hearing speakers for use as an alternative to speech during periods of mourning and in connection with male initiation rituals when silence must be observed. Four of the five handshapes in David's gestures are among the most frequent in the seven Aboriginal sign languages, and are the unmarked forms in those languages as well. The only one of David's handshapes that is relatively infrequent in the Aboriginal sign languages is the C handshape, which appears in four of the seven sign languages. In addition, all nine of the motions David used are found in the Aboriginal sign languages.

David's system of gestures is, however, much more restricted than either

ASL or the Aboriginal sign languages described by Kendon. ASL makes use of many more handshape and motion forms than the limited set described for David's gestures. Wilbur (1987) lists 36 different handshape forms that appear in the frozen signs of ASL, and 21 that are used as classifiers in the productive signs of ASL. In terms of motions, Klima & Bellugi (1979) describe a set of rather complex motions that serve as inflectional markers in ASL (e.g. a single thrustlike movement combining a brief tense motion with a circular motion and a lax, soft handshape; when an ASL sign such as SICK is inflected with the thrust modulation, the inflected form means 'to get sick easily' or 'to be susceptible to illness'). None of these movements has been observed in David's gestures. Like ASL, the Aboriginal sign languages make use of many more handshape forms than David: 45 different forms are used in toto across the seven languages, and each language uses from 22 to 35 different forms. However, the set of motions in these Aboriginal sign languages is not much larger than David's: only two motion forms appear in the Aboriginal sign languages but not in David's gestures, the finger snap, and the hand rapidly trembled (Kendon, 1987).

In sum, conventional manual communication systems appear to contain all of the handshape and motion forms that are found in David's gestures, although they also contain many forms that do not appear in David's gestures. Thus, the particular forms found in David's gestures appear to be basic forms, and as such might be expected to appear in any gestural system, spontaneous or conventional. There may, in fact, be processes unrelated to the sign system itself that make these forms particularly likely to appear in a manual communication system. For example, the handshapes that David used appear to be fundamentally linked to object perception and manipulation. Klatzky, McCloskey, Doherty, Pellegrino & Smith (1986) partitioned handshapes according to prehensility and the size of the contacting hand surface, a taxonomy resulting in four of the five handshapes found in David's gestures (Palm, Point, O, and C). Moreover, in hearing adults, Klatzky *et al.* found a direct relationship between this taxonomy and the structural and functional attributes of objects, suggesting that these particular handshapes may function at a general level as part of our system for apprehending objects.

Handshape and motion meanings

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 (i.e. change of location, change of position or orientation, change of shape, and no change; see Supalla, 1982). However, the details of the motion meanings in ASL and in David's system differ. For example, the Linear form in David's system represents change of location along an unspecified path; in ASL, the

linear form means move along a straight path. As a second example, David used three forms to represent change of shape (Open/Close, Bend, and Wiggle), while ASL uses four slightly different forms (Spread, Bend-flat, Bend-round, and Change-diameter, each of which reflects a change in the attributes of an object, Supalla, 1982). Moreover, as mentioned above, there is a large number of forms used in ASL to convey a wide range of inflectional and derivational meanings that have not been found in David's gestures (Klima & Bellugi, 1979).

In addition, David's use of handshapes to represent objects parallels closely the three ways handshapes are used in ASL (Wilbur, 1987: 91). (1) Handshapes represent the semantic class of an object (David's OBJECT handshape Palm representing vehicles and animate objects vs. ASL's semantic classifiers; see Supalla, 1982; Wilbur, Bernstein & Kantor, 1985). (2) Handshapes represent the visual-geometric characteristics of an object (David's remaining OBJECT handshapes vs. ASL's size and shape classifiers, cf. Supalla, 1982; Schick, 1987). (3) Handshapes represent the handgrip used to manipulate an object (David's HAND handshapes vs. ASL's handle or instrumental classifiers; see McDonald, 1982; Schick, 1987). However, in each of these three categories, the set of handshapes available in ASL is much larger than David's set and consequently many more distinctions can be made in ASL than in David's system (see Wilbur *et al.* 1985). As an example from the semantic classifiers, David used one handshape, the Palm, to represent the category of vehicles and animate objects (i.e. self-propelling objects), while ASL has separate handshapes to represent humans, small animals, vehicles, airplanes, and boats (Supalla, 1982; see also Wilbur, 1987: 90). As an example from the size and shape classifiers, David used one handshape, the C, to represent all curved objects, while ASL has a series of handshapes that distinguish flat curved objects (a 1-fingered C), from shallow curved objects (a 2-fingered C), from deep curved objects (a 4-fingered C; Supalla 1982; see also Wilbur, 1987: 91-92). As a final example from the instrumental classifiers, David used the Palm to represent handling all large, flat surfaces, while ASL makes a distinction between handling a wide flattish bottomed object (flat palm with the thumb spread) vs. a flat plane (flat palm with the fingers spread; McDonald, 1982; see also Wilbur, 1987: 91-92).

Developmental comparisons to native ASL learners

When deaf children acquire ASL from their deaf parents, they tend at the earliest stages to use 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 in 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, vehicles, and airplanes (as did David), and one used the Palm for wide, flat, and cylindrical objects as well. Thus, even if provided with a conventional sign language model, deaf children tend to use the same simple forms for the same general categories as did David (see also Kantor, 1980; Schick, 1989). However, it is important to note that, even by age 3;6, the children in Supalla's study were correctly producing the more specified handshapes for humans, animals, vehicles, and airplanes on a substantial number of the stimuli – handshapes and distinctions not seen in David's gestures as late as age 4;10.

In addition, the course of David's gesture development was comparable to the development of signs in deaf children acquiring ASL (see Table 6). When first generating gestures, David seemed to have created each gesture to map onto a particular event; a stage reminiscent of the period during which deaf children acquiring ASL treat their morphologically complex signs as unanalysed wholes (Newport, 1984). Later in development, David began to use a single gesture to refer to a class of events – events that involved actions sharing a common attribute (represented by the motion component of the gesture) and objects sharing a common attribute (represented by the handshape component of the gesture). At this point, then, David's system can be described in terms of components of gesture forms mapping onto components of gesture meanings, rather than the whole gesture form mapping onto a global, particular event. This latter stage is comparable to the period when deaf children acquiring ASL begin to analyse the signs they have learned as wholes and separate these signs into meaningful components (Newport, 1984; see MacWhinney, 1978 and Bowerman, 1982, for descriptions of a similar developmental pattern in hearing children acquiring spoken language).

In sum, David's gesture system appears to contain a SUBSET of the handshape and motion components found in ASL. The similarities between sign forms in ASL and gesture forms in David's system suggest that David's set may reflect the units that are 'natural' to a visual/manual language – units that may form part of the basic framework not only for ASL morphology but also for the morphologies of other sign languages. An examination of the early stages of acquisition of sign languages other than ASL might shed light on this issue, as would observations of spontaneous gesture systems developed by deaf children without access to a conventional sign language in other cultures.

Gesture development in hearing children

David's gestures formed a morphological system that was far less complex than the morphological system of ASL, a conventional language with a long history and shared by a wide community of signers. The simplicity of David's system relative to ASL points to the importance of a community in generating and maintaining complexity in a linguistic system. Nevertheless, it is important to note that David's gestures did exhibit structural regularities and, in this sense, went beyond the gestures typically produced by hearing children learning spoken language. Hearing children in the early stages of spoken language development do indeed gesture, and certain communicative functions may even appear in gesture before they appear in speech (Goldin-Meadow & Morford, 1985; Volterra & Caselli, 1986). Not surprisingly, however, speech comes to dominate over gesture in the hearing child and this domination typically occurs before the child's gestures become complex. Thus, hearing children produce very few characterizing gestures overall (Petitto, 1988) and rarely, if ever, combine characterizing gestures with one another (Volterra, 1981).² Moreover, hearing children typically use many fewer different types of characterizing gestures than the deaf children in our studies (Goldin-Meadow & Morford, 1985). Finally, hearing children tend to use their characterizing gestures as names for particular objects (often non-transparent names developed in the context of interactive routines with parents, e.g. index fingers rubbed together to refer to a spider, Acredolo & Goodwyn, 1985, 1988) and, as such, their gestures do not appear to have the internal handshape and motion structure characteristic of David's gestures (nor, for that matter, do the gestures of hearing adults, cf. McNeill, 1987). The fact that the gestures of hearing children do not exhibit intra-gesture structure suggests that communication in the manual modality does not inevitably result in structure at the word level. While gesture used as a primary communication system (as in our deaf children) appears to assume intra-gesture structure, gesture used as an adjunct to speech does not necessarily do so.

We have previously referred to the language-like properties found in the deaf children's gestures as 'resilient' (Goldin-Meadow, 1982) – properties

[2] It is important to note that all 10 of the deaf subjects in our studies used characterizing + characterizing combinations. In her descriptions of our early work, Volterra (1981) mistakenly reported that our deaf subjects did not combine characterizing gestures with other characterizing gestures, which led her to suggest that conventional linguistic input is necessary for the child to be able to combine characterizing gestures. Volterra's claim was based on data from Goldin-Meadow (1979) and Feldman *et al.* (1978), both of which focus on simple one-proposition sentences and, as a result, do not discuss characterizing + characterizing combinations which are complex sentences in our coding scheme.

that appear in children's communication despite extensive variation of the learning conditions (such as no exposure to an established language). Properties that develop under such extreme conditions are likely to be among the most basic and indispensable for a structured system of human communication, and might be expected to be present in any coherent communication system. That these same resilient properties are not systematically used in the spontaneous gestures accompanying the speech of hearing children underscores (and continues to clarify by contrast) the 'language-like' nature of the deaf children's gestures.

STUDY 2: PARENTAL INPUT TO THE DEAF CHILD'S MORPHOLOGICAL SYSTEM

In Study 1 we found that (1) a limited set of discrete handshape and motion forms described the large majority of David's gestures, i.e. the forms were categorical rather than continuous; (2) each handshape or motion form was consistently associated with a particular meaning (or set of meanings) throughout the corpus, i.e. each form was meaningful; and (3) each handshape or motion form/meaning pairing could be found in more than one gesture, i.e. each form/meaning pairing was an independent morpheme that could combine with other morphemes in the system - the system was combinatorial.

David was not exposed to a conventional sign language during the time of our study and thus did not 'learn' his gestural system in the traditional sense of the word. Nevertheless, David was exposed to the spontaneous gestures his hearing parents used when speaking to him (as are hearing children of hearing parents, cf. Shatz, 1982; Bekken, 1989). These gestures could conceivably have served as input to David's gestural system and, therefore, must be the background against which his gestural accomplishments are evaluated.

In our previous analyses of parental input to sentence-level structure in David's gestures, we found that, although David's Mother did indeed gesture, she produced relatively few gesture strings. For example, in an analysis of the videotapes taken when David was 2;10, 2;11, 3;0, 3;3, 3;5 and 3;8, we found that David produced an average of 33.0 gesture strings per hour while Mother produced only 15.6. Moreover, the few gesture strings Mother did produce showed a different production probability pattern from the pattern found in David's strings, and (unlike David's strings) showed no gesture ordering consistencies whatsoever (Goldin-Meadow & Mylander, 1984).

However, during these same videotaped sessions, David's mother was found to produce single gestures more often than David. Mother produced an average of 62.5 single gestures per hour while David produced only 39.5.

In addition, for both Mother and David, a large proportion of their single gestures were characterizing (mimetic) gestures rather than deictic (pointing) gestures: 66% of Mother's single gestures were characterizing gestures, as were 61% of David's. Thus, David's mother produced a substantial number of characterizing gestures during the time when he was developing his morphological system, and these characterizing gestures may have served as a model for that system. The goal of Study 2 is to determine which aspects of David's morphological structure can be traced to the gestural input provided by his hearing mother and which aspects go beyond this input.

METHOD

All of the characterizing gestures produced by David's mother during the seven videotaped sessions analysed in Study 1 were coded and analysed. We included only those gestures Mother addressed to David (264 of the 371 characterizing gestures she produced on the seven videotapes), omitting from the analyses the 107 gestures accompanying communications to others in the room (e.g. hearing siblings, the experimenters, etc.).

We used the same procedures to code handshape and motion form in Mother's gestures as we used in David's gestures. To assess meaning in Mother's gestures, we evaluated the gestures she produced in terms of the form-meaning pairings established for David's handshapes and motions in Study 1. We compared Mother's gestures to David's in terms of handshape and motions forms, handshape and motion meanings, and handshape and motion combinations.

RESULTS

Handshape and motion forms

Mother was found to produce the same five handshape forms and the same nine motion forms as did David. Table 7 includes all of the 1-motion gestures produced by Mother and by David over the seven videotaped sessions, and presents the proportions of gestures Mother and David produced for each of the five handshape forms (upper portion) and for each of the nine motion forms (lower portion). The table also includes miscellaneous categories presenting the proportions of gestures that did not conform to the predominant handshape and motion categories. The data for both Mother and David are described almost completely by the five handshape and nine motion categories (i.e. the miscellaneous categories contain no more than 3% of either David's or Mother's gestures).

Although the repertoire of forms used by Mother and David was identical, there were differences in how often each form was used. With respect to

TABLE 7. Comparison of the forms of Mother's and David's gestures^a

	Handshape forms	
	Mother	David
Fist	0.11	0.20
O	0.10	0.30
C	0.05	0.07
Palm	0.53	0.30
Point	0.21	0.10
Miscellaneous	0.00	0.03 ^b
Total	219	398
	Motion forms	
	Mother	David
Linear Path	0.05	0.09
Long Arc	0.29	0.09
Short Arc	0.26	0.18
Arc To & Fro	0.13	0.27
Circular	0.06	0.10
Open/Close	0.05	0.04
Bend	0.00	0.01
Wiggle	0.02	0.01
No Motion	0.10	0.21
Miscellaneous	0.03	0.00
Total	262	439

^a All of the one-motion gestures produced by Mother and by David over the seven videotaped sessions are included in the table. Note that the forms produced by Mother and David are essentially described by the five handshape and nine motion categories. The total number of handshape forms is less than the total number of motion forms for both Mother and David because a number of gestures were produced while the gesturer was holding something in his or her hand, a manual analog of speaking with one's mouth full.

^b The handshape miscellaneous category for David includes three handshape forms (accounting for 11 gestures) which David used to represent single objects (a thumb handshape used to represent pushing a small button; an L handshape used to represent a gun; and a V handshape used to represent scissors). Because there was no evidence that these forms were used productively, these 11 handshapes are not listed in Table 2, nor were they included in the form/meaning analysis done on David's handshapes described in the text. If these handshapes are included as violations in the analysis, we still find that 92% (368/398) of David's handshape forms fit the form/meaning categories listed in Table 2.

handshapes, the Palm form accounted for over half of Mother's handshape forms but (although frequent) was no more likely to occur in David's gestures than the O handshape (which was relatively infrequent in Mother's gestures). With respect to motions, the Long Arc form was the most frequent form in Mother's gestures, while the Arc To & Fro form was most frequent in David's gestures (Table 7). Thus, David did not match his use of gestures to Mother's with strict form-by-form frequency.

Handshape and motion meanings

To determine whether Mother used her handshape and motion forms to convey the same meanings as David, we calculated the proportion of Mother's gestures that conformed to David's system of form-meaning pairings. For handshapes, we determined the proportion of handshape forms that Mother used to convey the meanings displayed in Table 2. For motions, we determined the proportion of motion forms that Mother used to convey the meanings displayed in Table 4. We found that only 50% of Mother's handshapes ($N = 219$) and 51% of Mother's motions ($N = 262$) conformed to David's system. In contrast, recall that 95% ($N = 398$) of David's handshapes and 90% ($N = 439$) of David's motions conformed to the system displayed in Tables 2 and 4. Moreover, 30% of the 110 handshapes Mother produced that did fit David's system were classified as Neutral Points – the handshape that, in a sense 'failed' the form/meaning pairing test (cf. Study 1, 'coding handshape forms and meanings') since it was used for a variety of objects that appeared to have no attributes in common. In contrast, only 6% of the 368 handshapes David produced that fit the system were Neutral Points. In addition, four of the morphemes in David's gestures (albeit the least frequent morphemes) were not found at all in Mother's gestures: three handshapes (OBJECT Fist, OBJECT O, OBJECT Palm: Particles) and one motion (Bend). Finally, the fit between Mother's meanings and David's did not improve for either handshapes or motions over the two-year period during which the pair was observed. Table 8 presents the proportions of Mother's gestures conforming to David's handshape form-meaning pairings (upper portion) and to David's motion form-meaning pairings (lower portion) for each of the seven videotaped sessions. The data provide no evidence for any converging developmental pattern.

The gestures that Mother produced which failed to conform to David's system were of two types. First, many of Mother's handshape and motion forms could not be assigned a specific meaning. We attributed meaning to David's handshape and motion forms by interpreting these forms in context. For example, if David were to produce a swatting motion in the air, we would examine the ongoing events for clues as to what that motion might mean (e.g. if David were playing a game in which Mother builds up a tower and David hits it to knock it over, we would gloss the swatting motion as 'hit'). One quarter of the forms Mother produced could not be mapped onto objects or events in the context. For example, while sitting with David near an array of coloured toy fruits, Mother said 'yellow' and arced her hand from her lap to her chin and back to her lap (an arc to and fro motion). Since the motion in Mother's gesture did not mirror any aspect of the ongoing situation, we were unable to attribute an iconic meaning to the motion form. 27% of the handshapes ($N = 219$) and 27% of the motions ($N = 262$) Mother produced were of this type and were classified as uninterpretable.

TABLE 8. *Proportion of Mother's gestures conforming to David's system of form-meaning pairings over time^a*

David's age	Proportion of Mother's handshapes conforming to David's handshape form-meaning pairings	Total Mother's handshapes
2;10	0.47	17
2;11	0.53	43
3;0	0.50	10
3;3	0.53	76
3;5	0.59	27
3;11	0.36	25
4;10	0.43	21

David's age	Proportion of Mother's motions conforming to David's motion form-meaning pairings	Total Mother's motions
2;10	0.56	18
3;11	0.47	55
3;0	0.47	15
3;3	0.55	86
3;5	0.61	36
3;11	0.37	30
4;10	0.50	22

^a All of the one-motion gestures produced by Mother over the seven videotaped sessions are included in the table. For comparison, recall that 95% ($N = 187$) of the handshapes and 90% ($N = 439$) of the motions in the one-motion gestures David produced conformed to the system of handshape and motion form-meaning pairing displayed in Tables 2 and 4 (see text).

In addition, Mother often produced gestures whose meanings were clear but did not match the meanings of David's gestures: 23% of Mother's handshapes ($N = 219$) and 23% of Mother's motions ($N = 262$) were of this type. For example, although Mother used her Palm handshape for the same sets of meanings as David (see Table 2), she also frequently used the form for a range of other meanings (e.g. handle a small, short object; handle a large object; a round object; a curved object): 46% of the 63 (interpretable) Palm handshapes Mother produced were used to convey these other meanings, compared to 6% of the 118 Palm handshapes David produced. Similarly for motions, although Mother used her Short Arc motion for the same meanings as David (see Table 4), she also frequently used the form for a range of other meanings (e.g. change location; hold an object in place; move hand to contact an object): 47% of the 58 (interpretable) Short Arc motions Mother produced were used to convey these other meanings, compared to 9% of the 80 Short Arc motions David produced. Thus, even when Mother produced

gesture forms that were interpretable, the meanings of those forms were less constrained than were the meanings of David's forms.

Handshape and motion combinations

We classified all of Mother's gestures conforming to David's form-meaning pairings for handshape (cf. Table 2) and for motions (cf. Table 4) according to the particular handshape/motion combination displayed in each gesture. We fitted Mother's gestures into the handshape/motion matrix established for David (cf. Table 5) and found that Mother's handshape/motion combinations essentially comprised a subset of the combinations David produced. David produced 80% of the 25 different types of handshape/motion combinations Mother produced, while Mother produced only 37% of the 54 combinations David produced. Thus, 62% of the 54 combinations David produced could not be found in Mother's repertoire. Consequently, even if David took Mother's gestures as a model for certain handshape/motion combinations, he must have generalized beyond that input in order to produce the relatively large number of combinations found in his gestures alone.

Finally, in contrast to David, Mother used her handshape/motion combinations to refer to individual events rather than classes of events (e.g. Mother might use the C-hand combined with a Circular motion only to refer to opening a jar and to no other types of actions or objects, while David would use the C-hand + Circular motion combination to refer to opening a jar, rotating a wide knob, moving a train in a circle, etc.). Table 9 presents the number of different types of handshape/motion combinations Mother used

TABLE 9. *Mother's use of gestures to refer to an individual event vs. a class of events^a*

David's age	Number of different types of handshape/motion combinations	
	Referring to an individual event	Referring to a class of events
2;10	3	1
2;11	9	0
3;0	3	0
3;3	9	4
3;5	8	1
3;11	5	0
4;10	4	1

^a The numbers at each age represent the total number of different types of handshape/motion combinations Mother used, classified according to whether each combination was used to refer to an individual event vs. a class of events.

to refer to an individual event vs. a class of events at each of the seven videotaped sessions (only the subset of Mother's gestures that conformed to David's handshape and motion meanings is included in the table). Mother did not show a developmental pattern comparable to David's (see Table 6); there was no time during the seven sessions after which Mother began to consistently and robustly use a number of different handshape/motion combinations to refer to classes of events. Thus, unlike David, Mother appears to have used most of her handshape/motion combinations as labels for individual events, a strategy suggesting that Mother treated each gesture as an unanalysed whole.

DISCUSSION

We found in Study 1 that David's gestures could be characterized by a productive system of handshape and motion components. Could Mother's gestures have served as a model for this productive system? All but four of the handshape and motion morphemes that characterized David's system could be found in Mother's gestures and, in this sense, Mother's gestures may have provided a model for David. However, Mother used the form-meaning pairings found in David's gestures only 50% of the time, making it necessary for David to filter his Mother's gestures in order to use them as a model. One possible sieve that David might have used to filter Mother's gestures is comprehensibility; that is, David may have selected only those gestures that he found comprehensible as a model for his system. Indeed, approximately 25% of all of the gestures Mother produced were uninterpretable to us and were likely to have been uninterpretable to the child as well. Of the remaining 75% two-thirds fit David's system and could have served as a (still somewhat noisy) model for David's gestures.

Thus, our data are consistent with the hypothesis that David may have made use of Mother's gestures, albeit in filtered form, as a basis for constructing the units of his morphological system. However, it is important to note that David had gone beyond Mother's gestures, generalizing in two directions: (1) David produced almost all of the handshape/motion combinations that Mother produced (20 of Mother's 25) but, in addition, produced another 34 combinations that were not found in Mother's repertoire. In order to go beyond Mother's gestures as he did, David must have isolated the handshape and motion dimensions and used them as a basis for generating his novel combinations; (2) Mother used her gestures to refer to individual events, while David used his to refer to classes of related events. Thus, in constructing the referents of his gestures, David generalized beyond individual events, using the internal handshape and motion structure of his gestures as the basis for those generalizations.

In sum, there appeared to be sufficient structure in Mother's gestures to

allow David to use those gestures in constructing word-level structure. But, if he did make use of this input, David must have searched through a fair amount of noise in order to arrive at the structure in Mother's gestures. Moreover, David treated the structure in Mother's gestures as a starting point, using it to generalize to novel combinations and to novel referential uses.

David's process of sifting through and organizing the gestural input available to him is comparable to the process postulated for a deaf child developing ASL on the basis of less-than-perfect input. Singleton & Newport (1987) have described the morphological competence of one deaf child, named Simon, whose language-learning situation was unusual in that his only source of ASL input came from his deaf parents who learned ASL after the age of 15. When presented with filmed events designed to test knowledge of ASL morphology, Simon's parents performed below the level achieved by deaf adults who learned ASL from birth. Despite the fact that this imperfect model was Simon's only contact with ASL, Simon's performance on the morphology tests was excellent, equalling the test scores of deaf children exposed to intact models of ASL and exceeding the test scores of his parents. Simon altered the input provided by his parents in two ways: (1) On tests of stem morphology in verbs of motion, Simon's parents' most frequent response to each morpheme was, in fact, almost always the correct response and the response given by Simon. However, Simon at age seven, gave this correct response more frequently than his parents (Singleton, 1987). Thus, there was a certain amount of noise that Simon had to search through in order to discover the morphological regularity in his parents' signs. (2) On tests of aspect/number verb inflection, Simon's parents performed accurately on singly-inflected verb forms but not on multiply-inflected forms. In contrast, Simon, at age nine exhibited proficiency on both forms, recursively applying the appropriate single inflections to arrive at the correct multiply-inflected forms (Singleton, 1989). Thus, Simon had generalized beyond his parents' systems, combining inflections despite the fact that he had not received an explicit model for such combinations.

Both Simon and David appeared to have gone beyond the input they received, finding structure in noisy arrays and using that structure to generalize beyond their models. In this sense, we suggest that the children seemed to be 'ready' to find structure in their respective inputs. Nevertheless, it is important to note that the type of structure available in those inputs was crucial in determining the complexity of the linguistic system each child developed. David was exposed to an array of gestures that his hearing mother used as an adjunct to speech and, by a process of sifting and restructuring, may have developed the rudiments of a morphological system out of those gestures. In contrast, Simon applied those same processes of sifting and restructuring to input (albeit inconsistent input) from a conventional sign

language and developed a well-formed, organized morphological system that was virtually indistinguishable from the morphological systems developed by deaf children learning ASL from intact models. Thus, not surprisingly, the complexity of the inputs the children received played a significant role in determining the complexity of the morphological system each child induced.

We have shown that the morphological structure David developed in his gestures was, at least in part, 'out there' in his Mother's gestures waiting to be discovered. However, it is important to stress that the morphological structure in Mother's gestures was well hidden. It is unlikely that we, as researchers, would have found morphological structure in Mother's gestures had we not looked for it with David's system in mind. Moreover, a description of Mother's gestures in terms of morphological structure may not be the best way to characterize those gestures; after all, there was a great deal of noise in Mother's gestures (particularly when considered from the point of view of David's system) and little evidence of productive or combinatorial regularities. Indeed, in his descriptions of the spontaneous gestures typically produced by hearing individuals, McNeill (1985) has shown that spontaneous gestures make little sense by themselves, but form an integrated system with speech and should be described in conjunction with speech. McNeill (1987; in press) further notes that, in general, there is no composition out of parts (i.e. no system of contrasts) in the spontaneous gestures of hearing individuals and each gesture exhibits a meaning as a whole. Since all of Mother's gestures were produced with speech (not surprisingly, given that David's mother was committed to teaching her child spoken English), it is likely that Mother's gestures also formed an integrated system with speech. Many of Mother's gestures which were uninterpretable when analysed with the techniques developed to analyse David's gestures – a primary communication system – might have been quite meaningful when analysed with a system developed to code gesture in relation to speech (cf. McNeill, in press).

The morphological structure in Mother's gestures can be thought of as a hidden figure incorporated within the larger picture of Mother's gesture/speech system. Hidden figures are generally much easier to find if one knows that a figure is in fact somewhere in the picture, and if one knows what type of figure to search for. Given our knowledge of David's gesture system, we were able to find a (noisy) morphological structure within Mother's gestures. Extrapolating to David, we suggest that, in order to find morphological structure in Mother's gestures, David must have had a prior belief that there would be structure in those gestures, and a prior belief about what type of structure he would find.

As in the normal language-learning situation, structure was available for discovery in David's input. What makes David's situation unique is that there was far more noise obscuring the structure in David's input than in the typical language-learning situation. The fact that David could fashion the

rudiments of a morphological system out of the noisy and limited input available to him suggests that some aspects of linguistic analysis may be guided by factors internal to the child. At the very least, our data suggest that children will seek structure at the word level when developing systems for communication, and that they will recruit whatever input is available – conventional or otherwise – in order to develop that structure.

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