ONCE IS NOT ENOUGH: STANDARDS OF WELL-FORMEDNESS IN MANUAL COMMUNICATION CREATED OVER THREE DIFFERENT TIMESPANS

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Natural languages are characterized by standards of well-formedness. These internal standards are likely to be, at least in part, a product of a consensus achieved among the users of a language over time. Nevertheless, it is possible that an individual, attempting to invent symbols to communicate de novo, might generate a system of symbols that is similarly characterized by internal standards of well-formedness. In these studies, we explore this possibility by comparing (1) a conventional sign language used by a community of signers and passed down from generation to generation with (2) gestures invented by a deaf child over a period of years and (3) gestures invented by nonsigning hearing individuals on the spot. Thus, we compare communication in the manual modality created over three different timespans—historical, ontogenetic, and microgenetic—focusing on the extent to which the gestures become codified and adhere to internal standards in each of these timespans. Our findings suggest that an individual can introduce standards of well-formedness into a self-generated gesture system, but that gradual development over a period of time is necessary for such standards to be constructed.*

THE IMPORTANCE OF HISTORY TO LANGUAGE

1. Signed languages, like spoken languages, have developed over a historical timespan. As a result, the current form of a signed language such as American Sign Language (ASL) is a product of generations of use by a wide community of signers. A number of competing pressures have been identified which might have played a role in shaping the current forms of language, be they signed or spoken (Bloomfield 1933:346–95, Jakobson & Halle 1956:58–62, Sapir 1921: 186–89). For example, Slobin (1977) submits that the form a language takes is shaped, at least in part, by the requirement that language be semantically clear, and by the often competing requirement that language be processed efficiently and quickly. More specifically, Bever & Langendoen (1972) argue that the current form of the relative clause in spoken English has been shaped by historical competition between what makes a language easy to understand and what makes it easy to learn. Similar pressures have been identified as having influenced the current form of ASL. For example, Frishberg (1975) suggests that the evolution of compound signs into a single sign reflects how signs have changed to make the language easier to PRODUCE (e.g. RED + SLICE evolving to its current, single form TOMATO, a change which reduced the number of different handshapes and motions involved in the sign), while the tendency of

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signs to drift toward the middle of the signing space where they are more visible reflects how signs have changed to make the language easier to PERCEIVE (e.g. HELP articulated at the elbow evolving to its current form, in which it is articulated at the hand, a change that brought the sign closer to the central signing space).

Although there are various causes of internally-motivated language change, in both spoken (Sapir 1921:186–89) and signed (Frishberg 1975) languages, the changes themselves are not indiscriminate. Rather, they conform to the language's internal systematic tendencies. What this means for ASL—a language which has been noted for its iconic nature—is that there is often a loss in iconicity and transparency as signs evolve to fit the linguistic tendencies of the system (Frishberg 1975, Klima & Bellugi 1979:67–83). For example, the sign STEAL was previously produced with the moving hand making a grasping motion behind a stationary upper arm. Today, this sign is produced with a bent-V as the moving hand—a less transparent rendition of stealing but one that serves to link the sign to other signs which denote offensive behavior and are performed with a bent-V handshape (Frishberg 1975).

In this paper, we explore the forces propelling a communication system toward standards of well-formedness viewed along the dimension of time. For conventional languages, the internal standards that guide language change are likely to be, at least in part, a product of a consensus achieved among language users over time measured in generations. However, it is not clear whether such consensus over time is necessary for a linguistic system to be characterized by standards of well-formedness. For example, it is possible that an individual, attempting to invent symbols to communicate de novo (either over a period of years or within minutes 'on the spot'), might generate a system of symbols that is also characterized by internal standards. We will explore this possibility by comparing a conventional language, used by a community and passed down from generation to generation, with symbols invented by individuals either over a period of years or on the spot without the benefit of social consensus.

We focus on communication in the manual modality for two reasons. First, the iconicity of the modality makes it possible for an individual to invent gestural symbols that can be understood immediately (e.g. pantomime); and second, data exist describing the gesture systems developed over years by children who have never been exposed to culturally shared sign systems (Goldin-Meadow & Mylander 1984; see also Kuschel 1973 and Yau 1985, each of whom describes a sign system invented by an isolated deaf individual, and Kendon 1980, Shuman 1980, and Washabaugh et al. 1978, who describe sign languages that have arisen in isolated populations of deaf individuals). Thus, in this article we compare communication in the manual modality created over three different timespans: (1) ASL, that is, signs developed over a HISTORICAL timespan; (2) home sign, gestures developed over a period of years by a deaf child of hearing parents who have not yet exposed their child to ASL—that is, gestures developed over an ONTOGENETIC timespan; and (3) invented gestures, gestures created on the spot by hearing individuals who have no knowledge of ASL or any other sign language and who have been asked by an experimenter to use their hands and not their mouths to describe a series of scenes—that is, gestures developed over a MICROGENETIC timespan. In each timespan, we focus on the extent to which manual communication becomes codified into a system with internal standards of well-formedness.

In addition, we note that the home signer in our study was, in effect, deprived of all primary linguistic input, although he experienced an otherwise normal and positive upbringing. Cases such as this child's bear on the question of how important linguistic input is to the development of language-like structure. In particular, such cases allow us to determine which aspects of language can be reinvented by a child developing a communication system in the absence of a conventional language model (see Goldin-Meadow & Mylander 1990a for discussion of this issue). We focus here particularly on the importance of a conventional language model in creating structure internal to the word or sign, that is, in creating morphological structure.

STUDY 1

2.1. THE VERBS OF MOTION PRODUCTION TEST. One highly codified aspect of ASL is the morphology of verbs of motion. Newport & Supalla (1992; Newport 1990) have shown that verbs of motion in ASL contain as many as six simultaneously produced morphemes affixed upon a single verb stem. Moreover, Supalla (1982) has developed a test to assess knowledge of verbs of motion in native ASL signers (the Verbs of Motion Production [VMP] test). Since this test can easily be adapted for use with subjects who are not familiar with ASL, we chose to use it to investigate the home sign system of a deaf child and the invented gestures of nonsigning hearing individuals. Thus, in all three studies described here, we explore the structural organization of gestures created to encode events that are typically encoded by verbs of motion in ASL, and we compare the results to findings on native signers of ASL reported in Singleton & Newport 1993. We begin Study 1 with a description of ASL morphology in general and the structure of ASL verbs of motion in particular.

2.2. MORPHOLOGY IN ASL. Research on ASL morphology (see Wilbur 1987 for a general review) has focused on inflectional morphology which marks aspect and distribution on verbs and pluralization on nouns (Fischer 1973, Fischer & Gough 1978, Klima & Bellugi 1979:272–315), and on derivational morphology which distinguishes verb stems from related noun stems (Supalla & Newport 1978). As in spoken languages, stems in ASL undergo a variety of inflectional processes that apply in an ordered and recursive fashion.

Moreover, ASL appears to be comparable to those spoken languages whose word stems are morphologically complex. Mimetic signs in ASL (as contrasted with the 'frozen' signs of ASL that are listed in ASL dictionaries as single-morpheme stems) 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 et al. 1977). In other words, mimetic signs 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. More recently, however, several researchers have shown that these mimetic signs are composed of combinations of a limited set of discrete morphemes (McDonald 1982:41–102, Newport 1981, Schick 1987:8–37, Supalla 1982:8–23). 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.

Supalla (1982) designed his VMP test to explore the types of morpheme categories that constitute the primary morphology of ASL verbs of motion: five motion/location morpheme categories (ROOT, ORIENTATION, MANNER, LOCATION, POSITION), and two handshape morpheme categories (CENTRAL OBJECT and SECONDARY OBJECT). Every ASL verb of motion requires at least a CENTRAL OBJECT handshape morpheme indicating the class of the object that is moving, that is, its category (e.g. a human or a vehicle) or its shape (e.g. round or straight) and a ROOT motion morpheme indicating the type of path traversed by the moving object (e.g. a linear path, an arced path, or a circle). For example (Supalla 1982:23–44, 1986), the ROOT morpheme 'linear path' (representing change of location along a straight path) can be combined with one of many possible CENTRAL OBJECT morphemes representing the moving object—e.g., bent V = a small animal, and thumb pointing up with the index and middle fingers extended = a vehicle. These combinations create a set of signs whose meanings are predictable from the meanings of the individual motion and handshape morphemes (i.e., a small animal moves along a straight path or a vehicle moves along a straight path). In another example, the ROOT morpheme 'arc path', representing change of location along an arced path such as a jump forward, can be combined with these same CENTRAL OBJECT morphemes to create a set of signs whose meanings are also systematic combinations of the component parts of each sign (e.g., a small animal jumps forward or a vehicle jumps forward).

Along with the ROOT and CENTRAL OBJECT morphemes that are requisite in every verb of motion, the verb may also contain a variety of other morphemes (Supalla 1982:44–62). If the moving object has a special manner of motion along its path (e.g. bouncing or rolling), a MANNER morpheme is added to the verb. If the moving object has a special orientation or direction of motion (e.g. moving backwards or upwards), an ORIENTATION morpheme is added to the verb. Finally, if the moving object moves in relation to a second object, a classifier for the SECONDARY OBJECT (e.g. small animal or vehicle) is added, as well as a POSITION morpheme indicating the spatial relation of the secondary object relative to the path (e.g. the beginning or end of the path) and a LOCATION morpheme indicating the spatial relation of the central object relative to the secondary object at their point of contact (e.g. inside or on top of it).

All of the types of morphemes described above appear in many spoken languages that have morphologically complex verbs of motion. However, in ASL the forms of many of the morphemes are more iconic than their analogues in spoken languages are (Singleton & Newport 1993), so that a gesturer who doesn't know ASL might spontaneously invent gestural symbols that resemble the ASL morphemes. In Study 1, therefore, we ask whether a deaf child whose hearing parents have not yet exposed him to ASL will nevertheless invent gestures composed of parts that resemble ASL morphemes. If not, we ask whether the child's gestures, although distinct from ASL, are nonetheless consistent within themselves.

2.3. METHOD. The VMP test was administered to one deaf child of hearing parents who has been shown in previous work (Goldin-Meadow & Feldman 1977, Feldman et al. 1978) to have developed a gestural system which he used to communicate with the hearing individuals around him—that is, a 'home sign' system. We begin by describing the subject's linguistic background, and the materials and procedures used in administering the test to him.

2.3.1. SUBJECT. Deaf children born to deaf parents and exposed from birth to a conventional sign language such as ASL acquire that language naturally; that is, in acquiring sign language these children progress through stages similar to those of hearing children acquiring a spoken language (Newport & Meier 1985). 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, i.e. 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, Geers & Moog 1978, K. Meadow 1968, Quigley & Paul 1984:85–89). Moreover, although many hearing parents of deaf children send their children to schools in which one of the manually coded systems of English is taught, some hearing parents choose to send their deaf children to 'oral' schools which emphasize speech and in which sign systems are neither taught nor encouraged; these deaf children are not likely to receive input in a conventional sign system.

The subject of this study, whom we call David, is profoundly deaf (>90dB bilateral hearing loss), and his hearing parents chose to educate him using an oral method. David participated in a longitudinal study conducted by Goldin-Meadow and her colleagues to explore the gestures developed by deaf children whose hearing losses prevent them from naturally acquiring the spoken language that surrounds them, and whose hearing parents have not yet exposed them to any form of a conventional sign system. As a participant in this study, David was videotaped periodically in play sessions at his home, beginning at age 2;10. Despite his lack of a usable conventional language model, David was shown to have developed a gesture system that had many of the properties of language, particularly when compared to the linguistic systems developed by comparably aged children exposed to conventional language models (Goldin-Meadow & Mylander 1990a). In particular, there were compelling structural similarities between David's gestural system and conventional languages at the lexical (Feldman et al. 1978, Goldin-Meadow, Butcher, Mylander, & Dodge 1993), syntactic (Goldin-Meadow 1982, 1987, Goldin-Meadow & Feldman 1977, Goldin-Meadow & Mylander 1984), and morphological (Goldin-Meadow & Mylander 1990b, Goldin-Meadow, Mylander, & Butcher 1993) levels, and functional similarities in the way the gestures and conventional systems were used (Butcher et al. 1991).

The VMP test was administered to David in his home, when he was 9;5, by Elissa Newport and Ted Supalla in conjunction with one of us (SGM). At the time of this session, David had made little progress in oral language, occasionally producing single words but rarely combining those words into sentences. In addition, at this time David had had very limited exposure to ASL or to a manual code of English. One of the primary reasons we were convinced that David had only limited exposure to a conventional sign system was that he knew very few of even the most common lexical items of ASL or Manually Coded English, despite the fact that he was a superb gesturer. Moreover, when a native signer reviewed the tape taken of this session, she found that, while David did produce some ASL signs (TREE, GIRL, DOG), he failed to produce many ASL signs that are commonly known to young signers, and produced his own gestures instead (e.g., rather than produce the sign KING, David traced the outline of a crown on his head to refer to a king).

2.3.2. Materials and procedures. The VMP test developed by Supalla (1982; see also Supalla et al. 1993) is composed of 120 short filmed events of toy people and objects that move in varying paths and manners of motion, e.g. a doll jumping into a hoop or a robot moving past a motorcycle. Each test item is constructed to elicit a single verb of motion, and the items are balanced over the test so that roughly an equal number of items will test each morpheme of interest. Over the entire test, the subject's control of individual morphemes and morpheme categories can be evaluated.

The animated film segments, each 1–2 seconds in length, were shown to David one at a time. After each filmed event David was asked by Supalla, primarily through gesture, to depict what happened. After he took the test once, David was asked to retake it, but this time in conjunction with his hearing sister (whose data will be described in §4 below). The entire session was videotaped, and David's videotaped responses were later coded by a native signer trained by Supalla for the seven types of ASL morphemes described above. Each response was scored for accuracy according to targets previously established for native ASL usage. The targets were determined by Supalla (1982) through linguistic analyses of verbs of motion in ASL, and were subsequently verified by testing native ASL signers (Newport & Supalla 1992). David was assigned a score on each of the seven morpheme categories (the number of morpheme tokens which he produced correctly within a morpheme category, e.g. ROOT or CENTRAL OBJECT). In addition, David's responses were analyzed a second time (as described below) in order to determine whether his gestures, where they differed from ASL, nonetheless formed an internally consistent system within themselves.

2.4. RESULTS. We found that David was able to represent gesturally many aspects of the filmed segments in the VMP test. We begin by determining how accurate David's gestural representations were when evaluated according to the standards established for ASL.

2.4.1. ACCURACY ON ASL MORPHEMES. Table 1 presents the proportion of items in each of the seven morpheme categories that David produced correctly according to the targets established for ASL. For purposes of comparison, we include in Table 1 data from Singleton & Newport 1993 on native signers, 8 adults and 8 children (ranging in age from 6;1 to 10;10), all of whom were profoundly deaf. Note that David did very well on all of the motion and location morphemes. Indeed, his combined score on these morphemes was 91% correct (see Figure 1). To determine whether David's motion/location score fell within the range of scores for the native signers, we converted his test score to a standardized z-score for the distribution of motion/location scores earned by the native signers.[1] We found that David's motion/location score fell within the 95% confidence interval of the distribution for the adult native signers (whose mean was 94%, z = −1.5, n.s.) and for the child native signers (whose mean was 85%, z = 1.5, n.s.); that is, his score could not be reliably distinguished from the scores of the native signers.

	MOTION			LOCATION		HANDSHAPE	
	Root	Orientation	Manner	Location	Position	Central Object	Secondary Object
HOME SIGNER							
David	.90	.95	.83	.91	.98	.45	.48
NATIVE SIGNERS[a]							
Adults (N = 8)	.94	.90	.90	.97	.98	.84	.80
	(.03)[b]	(.05)	(.06)	(.03)	(.02)	(.06)	(.10)
Children (N = 8)	.84	.80	.86	.87	.88	.69	.67
	(.01)	(.08)	(.05)	(.09)	(.08)	(.10)	(.12)

TABLE 1. Proportion of items correct on Verbs of Motion Production test for home signer and native signers.

[a] The data on the native signers are from Singleton & Newport 1993.

[b] The numbers in parentheses are standard deviations.

In contrast to his ASL-like performance on motion and location morphemes, David's handshapes had less in common with ASL. In fact, his combined score on the handshape morphemes was 46% correct (see Fig. 1)—a score which fell more than two standard deviations below the mean score both for the adult

[1] A z-score indicates how many standard deviations away from the mean a particular score is (the mean of a distribution of standardized scores is always 0 and the standard deviation is always 1), and thus shows the relative status of that score within a particular distribution (Hays 1963:186).

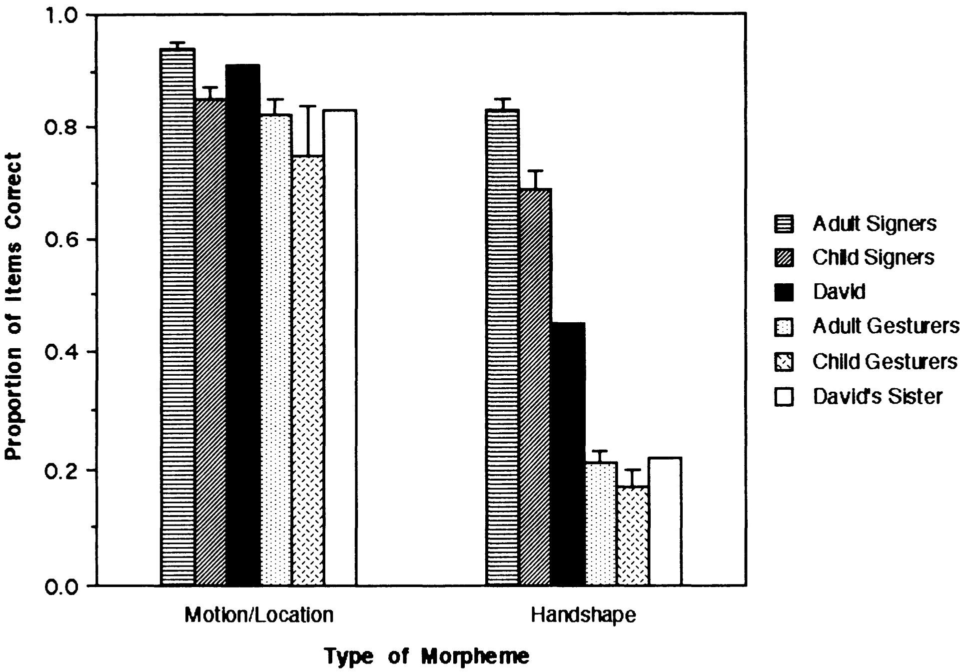

FIGURE 1. The proportion of correct responses (according to ASL targets) on the motion/location morphemes vs. the handshape morphemes for (1) native signers, both adults and children; (2) the home signer David; (3) novice gesturers, both adults and children; and (4) the home signer's hearing sister.

native signers (83%, $z = 6.25$, $p < .0001$) and for the child native signers (69%, $z = 2.35$, $p < .01$). We now turn to the question of whether David's handshapes, although different from ASL handshapes, nevertheless formed a consistent system.

2.4.2. ARE THERE INTERNAL STANDARDS WITHIN DAVID'S HANDSHAPES? To determine whether David's handshape forms were used systematically for particular categories of meanings, we first listed all of the different handshape forms that David used on the VMP test. Table 2 provides a description of the forms David used on the test and a tally of how often he used each form. The forms are divided into handshapes that are considered correct ASL responses on the VMP test and handshapes that are incorrect. Note that David used 8 of the 10 correct handshapes, failing to produce only the Vehicle handshape and the C-1-finger handshape. Indeed, 76% of the handshapes that David used on the test fell into the set of correct ASL handshapes. Thus, David's handshape forms tended to be ASL-like. However, the fact that his percent correct on the handshape morphemes was so low when calculated in terms of ASL targets (46%; see Fig. 1) suggests that he used those forms to represent different meanings from the ones they represent in ASL. In other words, David did not appear to be using ASL targets when responding to the items. Our question then was

Form	Description of form	Number of times David used a handshape form on the test
Correct handshapes on the VMP test		
Plane[a]	thumb, index, & pinky extended	5
Tree	spread hand & forearm held upright	6
Legs	spread index & middle fingers, pointing down	24
Vehicle	thumb pointing up, index & middle fingers extended	—
Palm	flat palm	61
2-fingers	index & middle fingers extended	1
Index	index finger extended	21
C-4-fingers	thumb & 4 fingers 3–5″ apart, hand shaped like a C	9
C-1-finger	thumb & index finger 3–5″ apart, 3 fingers curled into palm	—
C-F	thumb & index finger 3–5″ apart, 3 fingers extended	2
Incorrect handshapes on the VMP test[b]		
O-4-fingers	thumb & 4 fingers <2″ apart, hand shaped like an O	18
O-F	thumb & index finger <2″ apart, 3 fingers extended	6
Fist	fingers & thumb curled into palm	1
Hold	thumb & index finger positioned as though holding the object	10
Mime	hand positioned to act as the object or on the object	2
Trace	tip of finger traces path	2
Angled-palm	fingers straight, palm bent at knuckles	2
Curled-tree	spread hand, fingers curled, & forearm held upright	1
2-hand-round	two hands, fingers spread, forming a round shape	1

Table 2. Description and distribution of different handshape forms used by David on the Verbs of Motion Production test.[c]

[a] David also used a variant of the plane handshape in which he extended his thumb and pinky but not the index finger; in fact, 3 of his 5 plane handshapes had this form.

[b] Some of these handshapes (e.g. O-4-fingers, O-F, Fist) are acceptable handshapes in ASL; however, they are not the correct response for any of the items on the Verbs of Motion Production test.

[c] Other than the four semantic classifiers (Plane, Tree, Legs, and Vehicle), we have used labels for the handshapes that conform to the labels devised to describe David's system. These handshapes correspond to the following ASL forms (cf. Wilbur 1987): Palm = B; 2-fingers = H; Index = G; C-4-fingers = C; C-1-finger = similar to a C-letter handshape with the index finger and thumb forming the 'C' shape and the other 3 fingers curled into the palm; C-F = similar to a C-letter handshape with the index finger and thumb forming the 'C' shape and the other 3 fingers spread out as in an F handshape; O-4-fingers = O; Fist = A or S; Angled-palm = B with 3 dots; Curled-tree = 5 with 3 dots plus the forearm; 2-hand-round = two 5s with 3 dots held together with palms facing one another.

whether there were a set of consistent targets (call them 'David targets') that David used when responding to the VMP test. The difficulty, however, is in discovering the David targets.

To determine the targets for ASL, Supalla (1982) conducted a linguistic analysis of verbs of motion in ASL; these targets were subsequently verified by testing native ASL signers (Newport & Supalla 1992). Thus, responses to the VMP test were used, not to determine the ASL targets, but to verify the targets established on independent grounds. In order to follow a similar procedure for David, we attempted to establish targets on independent grounds and then to use his responses to the VMP test to verify those targets. Although we had no independent descriptions of David's morphological system at age 9;5 when the VMP test was given, we did have descriptions of his morphological system based on the spontaneous gestures he produced between the ages of 2;10 and 4;10 (Goldin-Meadow & Mylander 1990b). We used these descriptions as the basis for establishing David targets for the VMP test.

During this early period, David was found to use his handshapes in several different ways: (1) to represent the way in which a hand manipulates an object, a use that is reminiscent of handle classifiers in ASL (that is, the handshape represents a hand or instrument acting on an object; cf. McDonald 1982); (2) to represent the class of an object, a use that is reminiscent of semantic classifiers in ASL (that is, the handshape represents a class of objects that do not all look the same, e.g. the class of vehicles; cf. Supalla 1982); and (3) to represent certain perceptual characteristics of an object, a use that is reminiscent of size-and-shape classifiers in ASL (that is, the handshape represents dimensions of the object, its size and/or its shape; cf. Supalla 1982). The VMP test was designed to elicit both semantic classifiers and size-and-shape classifiers in native signers. We assigned to the particular handshape forms that David used on the test (cf. Table 2) the meanings that these forms had in his early morphological system. For example, the Palm handshape was used in David's early system both as a semantic classifier (to represent animate objects and vehicles, i.e. self-propelled objects) and as a size-and-shape classifier (to represent straight wide objects).

The meanings with which David's handshapes were associated in the spontaneous gestures he produced between age 2;10 and age 4;10 are displayed in Table 3, along with the meanings that are associated with those handshapes in ASL. There were two handshapes that David used multiple times on the VMP test and that he did not use during his early childhood—the Plane handshape and the Tree handshape. We could therefore attribute no meanings to these handshapes on the basis of his early system. However, both handshapes are used in ASL, as classifiers or as the handshape component of a frozen sign. As a result, we arbitrarily assigned to these handshapes the meanings they have in ASL (i.e. airplane and tree, respectively), on the assumption that David had learned these ASL signs from either a signer or a book in the years intervening since 4;10. Indeed, we found that, although David did not use the Plane and Tree classifiers on all of the items which required such handshapes (he did so on only 42% of the 12 items requiring Plane and 46% of the 13 items requiring

FORM	SEMANTIC CLASSIFIERS		SIZE-AND-SHAPE CLASSIFIERS	
	ASL TARGETS	DAVID TARGETS	ASL TARGETS	DAVID TARGETS
Plane	airplane	airplane		
Tree	tree	tree		
Legs	animate object			object with two skinny appendages
Vehicle	vehicle (excluding airplanes)			
Palm		animate object vehicle (including airplanes)	straight wide object	straight wide object
2-fingers			straight medium object	
Index			straight thin object	straight thin object
C-4-fingers			deep object with a round diameter	curved object
C-1-finger[a]			shallow object with a round diameter	
C-F[a]			shallow object with a round diameter	
O-4-fingers[b]				object with a round diameter
O-F[b]				object with a round diameter
DAVID'S FIT TO TARGETS	.42	.89	.49	.79

TABLE 3. Description of target meanings for handshape forms in ASL and in David's gestural system.

[a] C-1-finger and C-F are allomorphs in ASL.

[b] The O-F and O-4-fingers handshapes are acceptable handshapes in ASL; however, since the forms are not correct responses for any of the items on the Verbs of Motion Production test, they are not given meanings for ASL in this table. Neither handshape is a classifier in ASL, but both appear in frozen signs (e.g., the O-4-fingers is the base hand in the sign VOTE). Note that these two handshapes appear to be allomorphs in David's system.

Tree), whenever he did use one of these two handshapes, he used it appropriately to mean airplane or tree, respectively. (It is worth noting, however, that some of the novice gesturers tested in Study 2 used handshapes resembling the ASL Plane and Tree, suggesting that these forms are either iconic or widespread in the hearing culture; see §3.4.2.) We did not assign meanings in Table 3 to handshapes that David used only once or twice on the test (see Table 2). In addition, we did not include the Hold handshape in Table 3, simply because this handshape functioned as a handle classifier rather than as a semantic or size-and-shape classifier in David's morphological system (that is, the handshape represented how the object could be grasped rather than representing characteristics of the object itself; see Goldin-Meadow & Mylander 1990b).

Table 3 also displays the proportion of handshapes that David produced on the test that fit the ASL targets and the David targets. Note that the morphological system described for David on the basis of the spontaneous gestures he produced between the ages of 2;10 and 4;10 captured fairly well the responses he produced on the VMP test taken when he was 9;5. Overall, 82% of David's handshapes conformed to the David targets (compared to 46% conforming to the ASL targets). Indeed, for both semantic classifiers and size-and-shape classifiers, the David targets established on spontaneous data collected 5 years earlier provided a much better description of David's handshapes than did the ASL targets (see Table 3).

What were the differences between David's morphological system and ASL? Note first that David's system did not contain three of the nine ASL classifiers exemplified in the test: the Vehicle handshape meaning a vehicle (excluding airplanes), the 2-finger handshape meaning a straight medium object, and the C-1-finger and the C-F handshapes, both meaning a shallow object with a round diameter. It is particularly telling in terms of how little exposure David had to ASL that he failed to use the Vehicle classifier; this classifier is commonly used in ASL and is typically acquired well before age 9 (Supalla 1982:97, 119).

In addition to these omissions, some of the handshape forms in David's morphological system appeared to capture a different aspect of the object than the handshapes in ASL. David used handshapes shaped like an O—the O-4-fingers handshape (4 fingers and thumb in an O-shape) and the O-F handshape (1 finger and thumb in an O-shape, with 3 fingers extended)—to represent objects with a round diameter, such as a ring, a round swimming pool, or a doughnut. In David's system these handshapes contrasted with a handshape resembling a C—the C-4-fingers (4 fingers and thumb in a C-shape)—used to represent curved objects, such as the moon or the back of a turtle. The depth of the object did not appear to be encoded in David's handshapes; that is, he used the O-4-fingers for shallow objects with a round diameter (e.g. a thin ring), as well as for deep objects with a round diameter (e.g. a swimming pool or a cup). In contrast, C handshapes in ASL represent objects with a round diameter, and the number of fingers involved in the handshape represents the depth of the object (the fully closed O handshapes, i.e. O-F and O-4-fingers, are not acceptable ASL responses on this test). In other words, a C made in ASL with the index finger and thumb is used to represent shallow objects with a round diameter (e.g. a ring), while a C made with 4 fingers and thumb is used to represent deep objects with a round diameter (e.g. a swimming pool). Thus, although both ASL and David's morphological system have iconic properties, each system highlights different aspects of the object in its size-and-shape classifiers.[2]

[2] There were a number of instances on the VMP test when David used the C-4-fingers handshape not for curved objects (as described in Table 3) but for objects with a round diameter (objects

Moreover, note that in ASL the same handshape is not used as both a semantic classifier and a size-and-shape classifier. In David's system, by contrast, the Palm serves both as a size-and-shape classifier for straight, wide objects (as it does in ASL) and as a semantic classifier for animate objects and vehicles. We considered the Palm to be a semantic classifier in David's system simply because it was used to represent a variety of objects that did not necessarily have shape in common (i.e., the objects were not all straight and wide) but that did share the attribute of self-propulsion (i.e., the objects were either animate objects or vehicles). Note also that the category 'vehicle' encompasses different sets of objects in the two systems. A vehicle includes airplanes in David's system, but not in ASL. Thus, ASL tends to have a one-to-one mapping between forms and meanings (e.g., the Plane handshape represents airplanes and no other category, and airplanes are represented by Plane and no other handshape), while David's system allows a many-to-many mapping (e.g., Palm represents not only airplanes but also trucks, cars, animate objects, and straight wide objects; moreover, airplanes are represented not only by Palm but also by Plane).

Finally, Table 3 lists the Legs handshape as a semantic classifier for animate objects in ASL, and gives the same handshape as a size-and-shape classifier for objects with two skinny appendages in David's system. This difference between the two systems may be more apparent than real, however. In his early spontaneous gestures, David was found to use the Legs handshape to represent people (who have two skinny appendages as legs) as well as scissors (which have two skinny appendages as blades). Since the VMP test given to David at age 9;5 did not include objects such as scissors, it was impossible to tell whether David at this later age restricted his use of the Legs handshape to humans (which would then make the handshape comparable to a semantic classifier) or whether, if given the opportunity, he would continue to use the Legs handshape for objects like scissors (which would make it comparable to a size-and-shape classifier). It is interesting to note here that, while humans were represented by both the Palm handshape and the Legs handshape in David's early spontaneous gestures, in the VMP test humans were represented exclusively by the Legs handshape, suggesting that by the time David was 9;5 the handshape may indeed have become a semantic classifier in his system.

In sum, although David's handshapes and those used in ASL are comparable in many respects, there are real differences in the organization of the systems, confirming that David did not learn his system from an ASL signer. Moreover,

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which, in David's system, ought to be represented by an O handshape; cf. Table 3). However, all of these apparent exceptions were used to represent secondary objects into which a central object moved. For instance, David used a C handshape rather than an O to represent a pipe through which an airplane flies. It is, in fact, physically difficult to use an O handshape in instances of this sort, since the hand representing the airplane (the central object) does not fit easily into an O (representing the secondary object). We suspect that David used a C handshape (which allows for easier passage of the central object handshape into the secondary object handshape) rather than an O to accommodate the physical constraints of putting a large hand into a relatively narrow space. As a result, we did not count these as exceptions to David's system.

what is most striking is that David was as consistent within his own system as native signers are within theirs. Table 4 presents the proportion of correct handshapes used by David and the native signers (both the adults and the children) when those handshapes are scored according to the David targets for David, and according to the ASL targets for the signers. On both semantic classifiers and size-and-shape classifiers, David's performance on his system is comparable to the native signers' performance on ASL. Thus, David appears to have developed a handshape system that is characterized by internal consistency and, in this sense, by standards of well-formedness.

	SEMANTIC CLASSIFIERS	SIZE-AND-SHAPE CLASSIFIERS
HOME SIGNER ON HIS OWN TARGETS		
David	.89	.79
NATIVE SIGNERS ON ASL TARGETS		
Adults (N = 8)	.89	.78
	(.08)[a]	(.07)
Children (N = 8)	.79	.61
	(.06)	(.19)

TABLE 4. Proportion of correct handshapes used by David and native signers when scored according to their own targets.

[a] The numbers in parentheses are standard deviations.

2.5. THE HISTORICAL TIMESPAN VS. THE ONTOGENETIC TIMESPAN. We found that, when asked to describe scenes that are typically conveyed by verbs of motion in ASL, David constructed a set of gestures that were remarkably similar to the signs of ASL. Indeed, when we compared David's gestures with the ASL targets for motion and location morphemes, we found that David's motions and locations were virtually indistinguishable from those of ASL. It is worth stressing, however, that there may have been subtle and important differences from ASL in the way David used his motions—differences that we were unable to detect in our videotaped data. The items in the VMP test were constructed so that there was variation in the particular paths shown. This property of the test allows investigators to determine whether signers use a single form (e.g. a right-angled motion) to represent a variety of paths (e.g. a path with a 45-degree turn, a path with a 135-degree turn, etc.). Indeed, native signers, even young ones, do appear to use motion forms in a categorical way to represent a variety of paths (Singleton & Newport 1993). Although David also appeared to use his motion forms categorically, it is possible that he made very subtle distinctions among these forms which captured in a transparent way the actual variations displayed in the segments. It would be difficult to detect such small variations on our videotapes. David's motion morphemes may therefore not have been as categorical as those of ASL (but note that David's handshape forms were clearly used in a categorical fashion and, unlike the motion coding, we were relatively confident of our ability to detect small differences among handshape forms). Whether or not David's motions were categorical, the striking resemblance between the motions and locations that he developed and those of ASL suggests that these particular forms may be so basic to communication in the manual modality that they will emerge no matter how the system evolved. Thus, we might expect great commonality across conventional sign languages in the forms used to represent motions and locations—particularly when compared to the handshape classifier system, which David did not reinvent in its entirety and which therefore might show greater variability across sign languages. We return to this issue at the end of §3.

In contrast to his motion and location morphemes, which fitted neatly into the ASL system, David's handshape forms did not. He failed to use some of the most common handshapes that signers use on the VMP test, and he used some handshapes that signers never use on the test. Moreover, even when he did use the same handshapes as are used in ASL, he frequently used them to capture aspects of the object that differ from those captured in ASL handshapes. Nevertheless, what is impressive about David's handshapes is not their dissimilarity from ASL but the fact that they formed a coherent and internally consistent system, as do ASL handshapes. Indeed, David was as consistent within his own system as native signers were within the ASL system.

David developed his internally coherent morphological system without systematic exposure to ASL, having as input to his system only the spontaneous gestures that his hearing parents and hearing siblings used (see Goldin-Meadow & Mylander 1983, 1984, 1990b for a description of the spontaneous gestures that David's mother produced). The data therefore suggest that, even without the benefit of a conventional language model, a child can generate gestures which are characterized by a morphological system. Nevertheless, it is important to point out that the motion and handshape systems tested in the VMP test comprise only a small portion of the ASL morphological system. In particular, the VMP test focuses on a small set of verbs used to convey motion and location and the particular handshape classifiers that are permissible with these verbs. Supalla et al. (1993) have devised an extensive test battery to assess knowledge of a large number of ASL morphological and syntactic constructions (e.g. verbal inflections for aspect and number, subject-object agreement reversal, word order, and topicalization). David did develop a productive morphology—including stem-internal morphology (as we have shown here and in Goldin-Meadow & Mylander 1990b) and morphological markings distinguishing nouns from verbs (Goldin-Meadow, Butcher, Mylander, & Dodge 1993)—along with a productive syntax, including gesture-order and deletion rules (Feldman et al. 1978, Goldin-Meadow & Mylander 1984) and rules of recursion (Goldin-Meadow 1982, 1987). However, David's morphological system was quite simple—it had only five distinct handshapes and no handshapes composed of multimorphemic parts (Goldin-Meadow & Mylander 1990b)—as was his syntax, which had only a small number of rules describing the form of two-gesture strings (Goldin-Meadow & Mylander 1984). Thus, David developed a gesture system characterized by structure and consistency, but one with little complexity. It may be that complexity can be introduced into a linguistic system only if the system is used by a community of signers who transmit the system from one generation to the next. However, structure in and of itself apparently can be introduced into a linguistic system by a single individual.

The data described here indicate that David was able to construct a morphological system that is structurally similar to a very small portion of ASL grammar. What we find most interesting about this achievement is that, even in this very simple system, David appeared to rely on standards of form that guided the way in which he constructed his gestures. In other words, any gesture that David used was required, not only to convey the information displayed on the videotaped segment, but also to fit into a contrastive system of form-meaning categories—his choice of handshape provides information not only about the handshape used, but also about the set of handshapes NOT used. In this sense, David's gesture system can be said to possess standards of well-formedness of the sort that characterize conventional languages developed by communities of signers over long periods of time. Thus, it does not seem to be necessary for a communication system to be passed down from generation to generation in order for that system to be characterized by internal standards of form.

STUDY 2

3.1. We found in Study 1 that the gestures David developed to encode situations typically represented by verbs of motion in ASL were part of a coherent system with internal standards of form. In Study 2 we explore the possibility that these internal standards arise whenever an individual is asked to convey information of the sort displayed in the VMP test. To do so, we asked hearing individuals who had no knowledge of sign language to describe the segments in the VMP test using only their hands, that is, using gesture and no speech. Our goal was to determine whether the manual communication that an individual creates 'on the spot' is characterized by internal standards. To enhance comparisons with David, who was only 9 years old when tested, we tested a group of hearing children as well as hearing adults.

3.2. SUBJECTS. Sixteen hearing adults and 5 hearing children participated in the study. None of the hearing subjects had knowledge of ASL or any other sign language. The adults were all students at the University of Chicago, and were recruited through sign-up sheets distributed in psychology classes and posted in various campus buildings. The children, who ranged in age from 8;2 to 9;11, were recruited through an after-school program at a local school and had parental permission to participate in the study.

3.3. MATERIALS AND PROCEDURES. To make data collection more manageable, we used only a subset of the 120 segments which comprise the VMP test. We presented each subject with 38 segments. The segments were carefully selected so that there would be a sufficient number of exemplars in each of the seven morpheme categories within the sample. The test was administered by the same experimenter for all subjects (JS) in a quiet room at the University of Chicago. Each subject was first asked to view the segments and describe them; no mention was made of gesture for this first pass through the segments. (Data on the spontaneous gestures the subjects produced during this part of the study bear on the question of how gesture which accompanies speech differs from gesture which must carry the full burden of communication; preliminary results on this issue are described in Singleton et al. 1991, 1993.) The subject was then asked to view the segments again, this time using gesture and no speech to depict what happened in each segment.

The subjects' gestures produced without speech were scored initially according to the targets established for ASL (Supalla 1982) and then subsequently according to the targets established in Study 1 for David's gestures (cf. Table 3). Reliability for transcribing the form of the gestures was established by first training six nonsigners to code the gestures according to the system established by Supalla. Inter-coder reliability was then calculated between pairs of coders on a subset of the data, and was found to average 86% agreement. Reliability for classifying gestures according to ASL and David targets was established by having two trained observers (both of whom were fluent in ASL) independently code and classify the gestures of a subset of the subjects. There was 96% agreement between coders when they were classifying the gestures according to ASL targets, and 95% agreement between coders when they were classifying the gestures according to David targets.

3.4. Results. We found that novice gesturers, the hearing individuals with no knowledge of signed language, did not generate a system of gestures characterized by internal standards of form. We begin by comparing the novices' gestures to the standards established for ASL, and then we evaluate their gestures in terms of David's gesture system.

3.4.1. Accuracy on ASL morphemes. Table 5 shows the proportion of items in each of the seven morpheme categories which the home signer David and the novice gesturers, adults and children, produced correctly according to the targets established for ASL. The proportions listed for David in this table were calculated using only the 38 items that were identical to the items on which the hearing subjects were tested. Note that the novice gesturers (both adults and children) performed as well as David on the motion and location morphemes, but did far less well on the handshape morphemes. Indeed, as can be seen in Fig. 1, there was very little difference among all of the subjects on the motion/location morphemes, but there were rather dramatic differences between the gesturers and the signers (both the native signers and the home signer, David) on the handshape morphemes. Specifically, there were significant differences between the novice gesturers and the native signers on handshape for both adults ($t = 20.83$, $df = 22$, $p < .0001$) and children ($t = 10.241$, $df = 11$, $p < .0001$), but significant differences on motion/location only for adults ($t = 2.818$, $df = 22$, $p < .01$), not for children ($t = .778$, $df = 11$, n.s.). Moreover, David's score on the handshape morphemes fell more than two standard deviations above the mean for the adult novice gesturers ($z = 3.43$, $p < .001$) and for the child novice gesturers ($z = 3.50$, $p < .001$), but his score

	MOTION			LOCATION		HANDSHAPE	
	Root	Orientation	Manner	Location	Position	Central Object	Secondary Object
HOME SIGNER							
David[a]	.92	.92	.77	1.00	1.00	.53	.45
NOVICE GESTURERS							
Adults (N = 16)	.87	.81	.95	.73	.73	.20	.23
	(.07)[b]	(.09)	(.08)	(.27)	(.27)	(.07)	(.12)
Children (N = 5)	.84	.72	.95	.71	.71	.16	.19
	(.08)	(.09)	(.04)	(.33)	(.33)	(.06)	(.16)
David's hearing sister[c]	.85	.86	.74	.80	.88	.20	.28

TABLE 5. Proportion of items correct on Verbs of Motion Production test for home signer and novice gesturers.

[a] David's proportion correct in this table is calculated on the 38 items that are identical to the items on which the hearing adults and children were tested.

[b] The numbers in parentheses are standard deviations.

[c] David's hearing sister was tested on 60 items of the Verbs of Motion Production test; thus, her proportion correct in the table is calculated on the basis of 60 items. We analyzed for David the 60 items that are identical to the items on which his sister was tested, and found that his proportion correct on the 60 items was virtually identical to his proportion correct on the 38 items. We therefore present for David only his scores on the 38 items.

on motion/location morphemes fell within the 95% confidence interval for the adult novice distribution (z = .75, n.s.) and for the child novice distribution (z = .84, n.s.). Thus, the gestures produced by the novice gesturers resembled ASL in terms of motion and location but not in terms of handshape.

3.4.2. ACCURACY ON DAVID TARGETS. Although the novice gesturers' handshapes were different from those of ASL, they might have resembled the handshapes that David used on the VMP test, particularly since David's handshapes were invented with little or no input from a conventional system. To explore this possibility, we first determined which of the handshape forms described in Table 2 were used by the novice gesturers on the VMP test. Table 6 presents the proportion of the 16 adult gesturers and the 5 child gesturers who used each of these forms. Note that all of the forms listed on Table 2 (even the two forms that David did not use, the Vehicle and the C-1-finger) could be found somewhere in the gestures of the hearing novices. Even the Plane and Tree morphemes that we assume David learned either from a book or from a signer were found in the gestures of some of the novices (although the novice gesturers produced only the variant of Plane in which the pinky and thumb are extended and not the variant in which the index finger is extended as well; David produced both forms): 4 novice adults and 1 novice child produced the Plane handshape (and used it for airplane), and 7 novice adults and 1 novice child produced the Tree handshape (and used it for tree). Thus, the novice gesturers used all of the handshapes that David was found to use. However, it is important to point out that the novice gesturers also used many other handshapes that David did not use. The mean number of different handshape forms that the

Handshape form	Proportion of adults who used each form (N = 16)	Proportion of children who used each form (N = 5)
Correct handshapes on the VMP test		
Plane[a]	.25	.20
Tree	.50	.20
Legs	.31	—
Vehicle[b]	.06	.20
Palm	1.00	1.00
2-fingers	.75	.40
Index	.81	1.00
C-4-fingers	.88	.60
C-1-finger	.31	.20
C-F[b]	.19	—
Incorrect handshapes on the VMP test[c]		
O-4-fingers	.81	.80
O-F	.60	.80
Fist	.75	.80
Hold	.69	1.00
Mime	.25	.20
Trace	.38	.80
Angled-palm	.50	.60
Curled-tree	.38	.20
2-hand-round	.50	.40

Table 6. Proportion of the novice gesturers using the different handshape forms on the VMP test.

[a] The novice gesturers used the 'thumb and pinky extended' handshape form for Plane and did not produce the other variant found in David's gestures and in ASL (i.e. thumb, index, and pinky extended).

[b] These forms were not used by David on the VMP test, but they are handshapes that were used by native signers on the test.

[c] Some of these handshapes (e.g. O-4-fingers, O-F, Fist) are acceptable handshapes in ASL; however, they are not the correct response for any of the items on the Verbs of Motion Production test.

novice gesturers used on the 38 items was 20.3 ($SD = 5.9$) for the adult novices and 15.0 ($SD = 5.3$) for the child novices, compared to 10.0 for David (restricted to the 38 items).

We then recalculated the proportion of correct handshapes that the novice gesturers produced, but this time we evaluated their responses in terms of the David targets (cf. Table 3). We found that, when their performance was evaluated according to David targets, the adult novice gesturers achieved a score of 32% ($SD = .14$) and the child novice gesturers achieved a score of 41% ($SD = .12$), compared to 88% for David (restricted to the 38 items). Indeed, David's score was more than two standard deviations above the mean scores for both the adult novices ($z = 4.00$, $p < .0001$) and the child novices ($z = 3.92$, $p < .0001$).

Table 7 displays the proportion of correct responses for the novice gesturers

	SEMANTIC CLASSIFIERS		SIZE-AND-SHAPE CLASSIFIERS	
	ASL TARGETS	DAVID TARGETS	ASL TARGETS	DAVID TARGETS
HOME SIGNER				
David[a]	.48	.93	.52	.86
NOVICE GESTURERS				
Adults (N = 16)	.09	.31	.27	.32
	(.12)[b]	(.19)	(.11)	(.13)
Children (N = 5)	.10	.46	.24	.39
	(.07)	(.27)	(.07)	(.12)
David's hearing sister[c]	.11	.59	.33	.38

TABLE 7. Proportion of correct handshapes for the home signer and the novice gesturers when scored by ASL targets vs. targets for David's gestural system.

[a] David's proportion correct in this table is calculated on the 38 items that are identical to the items on which the hearing subjects were tested.

[b] The numbers in parentheses are standard deviations.

[c] David's hearing sister was tested on 60 items of the Verbs of Motion Production Test; thus, her proportion correct in the table is calculated on the basis of 60 items. We analyzed for David the 60 items that are identical to the items on which his sister was tested, and found that his proportion correct on the 60 items was virtually identical to his proportion correct on the 38 items. As a result, we present for David only his scores on the 38 items.

and for David (restricted to the 38 items), calculated according to ASL targets and David targets; the results are presented separately for semantic classifiers and for size-and-shape classifiers. Note that the novice gesturers were correct less often than David, whether their performance was evaluated according to ASL targets or to David targets—although the novices did, in fact, come closer to inventing the David targets than the ASL targets (i.e., their performance was better on the David targets than on the ASL targets). Moreover, the novice gesturers produced more correct responses on the size-and-shape classifiers (which are based on an iconic relationship between the referent and the gesture that represents that referent) than they did on the semantic classifiers (which have a relatively arbitrary relationship between referent and gesture) for ASL, but not for David targets. That is, they did no better on David's size-and-shape classifiers than they did on his semantic classifiers, presumably because both size-and-shape classifiers and semantic classifiers are relatively iconic in David's system.

In sum, the overall performance of the novice gesturers when evaluated according to ASL targets or David targets was not high, suggesting that the gestures produced by the novice gesturers were not identical to those of either native signers or the home signer. Nevertheless, even though the novice gesturers did not invent the handshape morphemes of either ASL or David's system, it is possible that the gestures produced by each novice did form a system with internal standards. We turn to this question in the next section.

3.4.3. INTERNAL STANDARDS WITHIN THE NOVICE GESTURERS' HANDSHAPES. To determine whether the novice gesturers might have used their gestures in an internally consistent manner, albeit adhering to standards different from those of either ASL or David, we investigated the consistency of their responses within a category. Specifically, we asked whether the novice gesturers tended to use a particular handshape for a class of objects, or whether they tended to treat each object within the class as unique. In re-examining the gestures produced by the novice gesturers, we focused on whether a subject used the same handshape every time an object appeared on the VMP test. For this analysis we selected categories of objects that appeared several times over the 38 items on which the novice gesturers were tested (e.g., there were 7 items on the test that involved an animal and 4 that involved people). Five categories of objects recurred frequently enough on the 38 items to test for consistency: animals (7 items), people (4 items), trees (4 items), wheeled vehicles (4 items), and airplanes (5 items). For each category, we determined the number of different handshapes that a subject used. For example, if a subject used the Index handshape in her gestures for all the items involving people, she would have a score of 1 for the people category; and if that same subject used the Index handshape and the Palm handshape in her gestures for the items involving animals, she would have a score of 2 for the animal category. We then calculated, for each subject, the mean number of different handshapes the subject used per category. Finally, we calculated the average number of different handshapes used per category by the group of adult novice gesturers and by the group of child novice gesturers.

We found that, on average, the adult novice gesturers used 3.2 different handshape forms per category (SD = .5) and the child novice gesturers used 2.9 different handshape forms per category (SD = .5). To put the scores of the novice gesturers in perspective, we performed the same analysis on David's gestures, analyzing the same subset of items from David's responses that we used for the novice gesturers. We found that David used 2.0 different handshape forms per category—a score which was more than two standard deviations below the combined mean for the adult and child novice gesturers ($z = -2.41$, $p < .01$). Importantly, the number of different handshapes that David used per category, although significantly lower than the number used by the novice gesturers, was NOT significantly different from the number used by native signers. We performed the same analysis on the signs produced by the eight child native signers, analyzing the same subset of items that we used for both David and the novice gesturers. We found that the child native signers produced 1.9 different handshapes per category (SD = .4). David's score of 2.0 fell within the 95% confidence interval for the distribution of scores for child native signers ($z = .25$, n.s.). Thus, David and the native signers were more likely than the novice gesturers to use the same handshape to represent an object each time it occurred on the test.

We submit that the significant difference in handshape variability found between David and the novice gesturers reflects a fundamental difference in the way these subjects generated gestures. When the novice gesturers generated a gesture, their goal was to produce a handshape that adequately represented the object, and their choice of handshapes appeared to be constrained only by their imaginations and the physical limitations imposed by the hands themselves. In contrast, when David generated a gesture, his choice of handshapes was (we suggest) guided not only by how well a handshape captured the features of an object, but also by how well that handshape fit into the set of handshapes allowed in his system. For example, one of the child novice gesturers produced a different handshape each of the five times she represented an airplane on the test. Each handshape captured an idiosyncratic property of the airplane pictured in the filmed event. The subject extended her thumb, index finger, and middle finger in an attempt to represent the wings and fuselage of the airplane in one segment. The same subject attempted to represent the wings of an airplane by holding her two flat palms together to make a V in a second segment, by placing one palm on top of the other to make an X in a third segment, and by producing the Plane handshape (thumb and pinky extended) in a fourth segment. In the fifth segment, this subject produced an O-1-finger handshape, representing the way the airplane, which was a paper plane, might have been thrown (although the airplane was not actually thrown in the videotape). In contrast to the novice gesturer, David used two different handshapes on the five airplane segments—the Palm and the Plane, both of which can be used to represent airplanes in his system. Thus, unlike the novice gesturers, whose choice of handshapes appeared to be constrained ONLY by the relationship between a handshape and the object it represented, David's choice of handshapes appeared to be constrained as well by the relationship between a particular handshape and the other handshapes in his system.

3.5. THE ONTOGENETIC TIMESPAN VS. THE MICROGENETIC TIMESPAN. In Study 2 we asked hearing individuals to abandon their native tongues and to use gesture to depict objects moving in space in a series of videotaped segments. We found that, in general, these novice gesturers did attempt to encode in their gestures information about the objects and paths displayed in the segments, and they did so with a certain amount of success. The gestures they created captured many of the characteristics of the objects and motions displayed in the segments, although there was very little consistency in the way a particular object was represented across the segments. The gestures that the novice gesturers created are best evaluated in terms of whether they were adequate to evoke the event displayed in the segment. In this sense, they are like pantomime, which is evaluated not in terms of well-formedness but rather in terms of its effectiveness in evoking the intended referent. For example, in pantomime it matters not at all how the hands are shaped in holding an imaginary egg, or how many fingers are straight or curved; what counts in pantomime is that the hands are held AS IF surrounding or holding an egg-shaped object (Bellugi & Klima 1976:520). The gestures that many of the novices in our study created were adequate to represent each individual object in the segments. Where the gestures failed was in representing the set of objects in a coherent and systematic fashion. The novice gesturers appeared to treat each gesture that they generated as an isolated symbol rather than as a member of a coherent set of symbols; that is, each of their gestures had a relationship to its referent but no relationship to their other gestures.

The novice gesturer thus appeared to strive for an effective representation of each individual filmed segment. This strategy led to gestures that resembled the motion and location morphemes of ASL (and of the gestures of the home signer) but not the handshape morphemes. It may be that the morphemes of ASL that represent motions and locations are closer to pantomime than the morphemes of ASL that represent objects. Thus, by attempting to generate gestures that capture the motions and locations of the segments, the novice gesturers have generated a system that resembles ASL and thus gives the appearance of having internal standards. However, the same strategy worked less well for the novice gesturers in terms of generating a system for handshapes. The handshapes the novice gesturers produced, although adequate representations of each individual object, did NOT cohere into a system for representing categories of objects (as did the handshapes that the home signer produced).

Our findings suggest that representing information in the manual modality is not the primary problem for the novice gesturer. The hearing gesturers successfully represented object, location, and movement information in their gestures. Rather, it is the organization of information into contrastive and productive categories that appears to be difficult to achieve on the spot and that may require the benefit of gradual development over a longer timespan.

STUDY 3

4.1. We have shown (§2) that a deaf child, lacking exposure to a usable conventional language, can develop a gestural system characterized by internal standards. Moreover, these internal standards do not appear to arise whenever an individual is asked to convey information of the sort displayed in the VMP test. The novice gesturers examined in Study 2, when asked to use gesture to describe the segments in the VMP test, generated gestures that adequately represented the objects; however, they did not generate a SYSTEM of gestures characterized by internal standards.

It may not be surprising that the novice gesturers failed to develop a system of gestures, for two reasons. First, they were forced to generate their gestures 'on the spot', with no time allowed for a system to evolve. Moreover, they were forced to generate their gestures on their own. We did not put two subjects together and ask them to communicate with one another; rather, the subjects were asked to convey to the experimenter, who clearly had seen the segments many times before, what happened in each segment. Thus, the subjects may not have felt they had a communication partner who was willing to enter into a system with them. It is possible that having such a partner is essential to generating a system of interrelated symbols (as opposed to a collection of unrelated symbols). To explore this possibility, we ask in Study 3 whether David had such a communication partner with whom he might have developed his system of gestures. It was fortunate that, at the time David took the VMP test, we also gave the test to his older hearing sister, with whom he often interacted. We therefore compared David's performance on the test to the performance of his hearing sister. Our goal was to determine whether the gestures produced by David's hearing sister fit his system. Such a finding would indicate that at some level his sister knew—and thus might have been a partner in creating—David's morphological system.

4.2. SUBJECT. The subject for this study was David's sister, who was 11;2—almost two years older than David—and had no hearing difficulties whatsoever. Her acquisition of spoken English was excellent and, at the time of the study, she had no knowledge of either ASL or Manually Coded English.

4.3. MATERIALS AND PROCEDURES. After David completed all 120 items on the test, he took the test a second time, but this time in conjunction with his hearing sister. David responded to an item and then his sister responded to the next item until all 120 items of the test had been shown. Since David used gesture to describe the filmed segments, his sister followed his lead and also performed the descriptive task using gesture only (i.e., she did not use her voice when describing the filmed segments). The 60 items that she responded to were scored initially according to the ASL targets and then according to the David targets (cf. Table 3).

4.4. RESULTS. We found that David's sister's gestures looked more like the gestures produced by the hearing novices than like the gestures produced by her brother David—despite the fact that she had had close contact with this home signer for many years. We compare the sister's gestures to the standards established for ASL and to David's gesture system.

4.4.1. ACCURACY ON ASL MORPHEMES. Look again at Table 5 to see the proportion of items in each of the seven morpheme categories which David's hearing sister produced correctly according to the targets established for ASL. Note that she performed as well as David did on the motion and location morphemes (X^2 = 2.46, df = 1, n.s.), but not on the handshape morphemes (X^2 = 12.375, df = 1, $p < .0001$). In all of the statistical comparisons of David's responses with those of his hearing sister, we used David's scores on the subset of the 120 item test (which he took earlier that day) that corresponded to the 60 items that his sister responded to; that is, we did the statistical analyses comparing the two children's performance on the same set of items. As can be seen in Fig. 1, David's hearing sister performed very much like the novice gesturers. Her percentage of correct motion/location morphemes (83%) and her percentage of correct handshape morphemes (22%) were both within the 95% confidence interval for the adult novice distribution (z = .08, n.s., for motion/location; z = .14, n.s., for handshape) and for the child novice distribution (z = .37, n.s., for motion/location; z = .63, n.s., for handshape). These data show, first, that the sister's responses were no different from those of any other hearing individual, adult or child, and, second, that David's sister, like the other hearing subjects, used handshapes which had less in common with ASL than did David's handshapes.

4.4.2. ACCURACY ON DAVID TARGETS. Our next step was to determine whether David's sister's handshapes, although different from those of ASL, were similar to the handshapes that David used on the VMP test. We recalculated the proportion of correct handshapes that she produced, but this time we evaluated her responses in terms of the David targets (cf. Table 3). We found that only 44% of the 85 handshapes on her 60-item test conformed to the David targets, compared to 86% for David (restricted to the same 85 handshapes, $X^2 = 31.55$, df = 1, $p < .0001$). In fact, David's hearing sister performed very much as the novice gesturers did on the David targets. Her percentage correct was within the 95% confidence interval for the adult novice distribution (z = .86, n.s.) and for the child novice distribution (z = .25, n.s.) on David targets.

See Table 7 again for the proportion of correct handshapes that David's sister produced, evaluated according to ASL targets and David targets; the proportions are presented separately for semantic classifiers and for size-and-shape classifiers. Note that David's sister was correct less often than David, regardless of whether her performance was evaluated according to ASL targets or David targets. Moreover, like the novice gesturers, David's sister produced more correct responses on the size-and-shape classifiers than she did on the semantic classifiers for ASL, but she did not show this pattern on the David targets.[3] In general, the fact that the proportions of correct responses displayed in Table 7 for David's sister were relatively low indicates that the sister's gestures did not resemble those of ASL, and—more tellingly—that they did not resemble the gestures of her deaf brother, with whom she interacted frequently.

4.4.3. INTERNAL STANDARDS WITHIN DAVID'S SISTER'S HANDSHAPES. We next asked whether, within a set of responses, David's sister used a particular handshape for a class of objects, or whether she treated each object within the class as unique. Thus, as we did for David and the novice gesturers, we calculated the mean number of different handshapes that she used per category. We found that she used 3.0 different handshape forms per category, more than David's 2.0 forms per category. In fact, her score was within the 95% confidence interval for the novice gesturer distribution (z = −.40, n.s.), but it was more than two standard deviations above the mean for the child native signers (z = 2.75, $p < .01$). Thus, unlike David and the native signers, but like the novice gesturers, David's sister tended to represent the same object with a variety of handshapes.

4.4.4. FURTHER EVIDENCE FOR STANDARDS OF FORM IN DAVID'S GESTURES. We showed in §2 that David generated a particular handshape not only with an eye toward how well that handshape represented its referent, but also with an eye toward how well the handshape conformed to the other handshapes in

[3] Note that David's sister appeared to do quite well on the semantic classifiers when they were coded according to David's targets. Her score, although reliably lower than David's ($X^2 = 2.62$, df = 1, $p < .02$), was higher than the novice gesturers' scores. However, this difference was not reliable: David's sister's score was within the 95% confidence interval for both the adult novice distribution (z = 1.47, n.s.) and the child novice distribution (z = .48, n.s.).

his system—that is, how well it fit within his system of handshape form-meaning mappings. In this sense, David's gestures (but not his sister's) can be said to adhere to standards of form.

One of Bellugi & Klima's 1976 arguments in support of the suggestion that ASL has standards of form is the fact that novice signers are corrected by fluent signers for producing the sign differently from the norm. For example, they describe a deaf mother who corrected her deaf child's signing when the sign EGG was made with four fingers outstretched instead of the accepted two. That there is a recognizably appropriate way to form the sign EGG—that there are, in fact, conditions of well-formedness in ASL—is indicated by the mother's correction of the child's 'mispronunciation' (Bellugi & Klima 1976:520). Although it is not necessary for a language user to correct another's 'mispronunciation' in order to show that the user adheres to standards of form (such corrections imply a certain level of consciousness which a user need not have), corrections of another's performance would provide further evidence of a standard. In fact, we found that, on a number of the 60 items that his sister responded to, David considered his sister's response to be inappropriate, and he corrected her. For example, she produced a Hold handshape (index and thumb extended as though holding a small object) to describe a tree in a particular segment. Reacting to her choice of handshape, David teased his sister by producing the Hold handshape himself, pretending to sign with it, and finally completely ridiculing the handshape when he used it to poke himself in the eyes. The sister then shrugged and said, 'Okay, so what should I do?'—a reaction which both acknowledged the fact that there was a system of which David was the keeper and admitted her ignorance of this system. David then indicated that an Index handshape (which is an appropriate handshape for straight thin objects and therefore an appropriate handshape for a tree) would be a correct way to respond to this item. Thus, David appeared to have a well-developed and articulated sense of what counted as an acceptable gesture, and he was not shy about informing others of his standards. He not only produced gestures that adhered to his standards, but he also imposed his standards on the gestures of another person, namely, his sister.

4.5. Time is not enough. The data presented in Study 3 suggest that David's hearing sister did not provide a model for the gestures that David used on the VMP test (and see Goldin-Meadow & Mylander 1983, 1984, and 1990b for evidence that the spontaneous gestures created by David's hearing mother also did not serve as a model for the morphological and syntactic regularities within his gesture system).[4] In addition, the data indicate that David's gestures did

[4] It is possible that David's sister (and the other hearing individuals in his family) played a role in shaping his gesture system by understanding and responding appropriately to certain forms, and failing to understand and respond to other forms. However, in previous work, when we examined the way in which his mother responded to his gestures, we found no evidence that the appropriateness of her response was in any way dependent upon the form of those gestures (Goldin-Meadow & Mylander 1983, 1984). These data suggest that whatever internal standards there were in David's gestures were likely to have been introduced by the deaf child himself, not by the hearing members of his family.

not serve as a model for his hearing sister's gestures. Despite the fact that David's sister had interacted with him on a daily basis for years, she did not display the morphology of his gesture system in her own gestures. Moreover, she did not even make use of the model that David provided at the moment. Recall that David and his sister took the VMP test together, a situation which meant, in effect, that David provided a gestural model for his sister on every other item; but this repeated reminder of what David's gestures were like did not cause his sister to produce gestures that resembled his. Indeed, her gestures looked very much like the gestures produced by hearing individuals who had no contact at all with a home signer. Thus, constant contact with a home sign system over a period of years was not enough to encourage David's sister either to develop a structured gestural system of her own or to learn David's.

Discussion

5.1. Once is not enough: Ontogenetic time is required to develop standards of form. McNeill (1992:36) argues that the comparison of codified signs (that is, conventional sign languages) and noncodified spontaneous gestures (that is, the gestures that speakers spontaneously produce along with their speech) within the same manual modality offers a unique view of the factors shaping language: holding constant the modality, we see which properties are invariant and which properties are added by the conventionally structured code. In his extensive studies of the gestures that hearing speakers spontaneously produce along with their speech, McNeill found that noncodified gestures differ from a sign system such as ASL in their lack of segmentation, compositionality, and standards of well-formedness. Thus, standards of form are NOT characteristic of the spontaneous gestures that speakers produce along with their speech; but they do arise when communication in the manual mode becomes codified into a conventional sign language.

In our studies, we have attempted to hold modality constant in order to explore whether a historically developed conventional code is the only communication situation which allows standards of form to evolve in the manual modality. In addition, we hold constant the fact that the manual modality carries the full burden of communication (unlike spontaneous gestures which accompany speech and serve an adjunct role relative to the spoken system; cf. Goldin-Meadow 1993). In this paper we have explored the question of whether it is necessary for a manual language to be passed down from generation to generation in order for standards of form to evolve, or whether an individual inventing gestures, either on the spot or over a period of years, can develop a manual system characterized by standards of form.

We found that, when an individual is asked to abandon speech and generate gestures on the spot to convey information, that individual—whether child or adult—is likely to be able to do so. Indeed, the gestures which are produced tend to be relatively good representations of the objects and movements to be described. However, the gestures do not form a coherent system. The overriding consideration for the novice gesturer appears to be to maximize the way the gesture relates to the world, rather than to maximize the way the gesture relates to other gestures. Although it is possible to invent gestures on the spot, then, the invented gestures are not likely to conform to internally coherent standards of well-formedness.

In contrast, we examined the gestures produced by a deaf child who, over a period of years, invented and used a spontaneous gesture system to communicate with his hearing parents and siblings. We found that his gestures not only were adequate representations of objects and movements in the world, but that they also conformed to an internally consistent and contrastive system; that is, they appeared to have standards of form. Further evidence that the deaf child's gesture system is characterized by standards of form comes from the fact that he spontaneously corrected some of his sister's gestures which did not conform to his gestural system. In addition, in an analysis of the spontaneous gestures that this child used over a two-year period, Goldin-Meadow, Butcher, Mylander, & Dodge (1993) found that he tended to use precisely the same gestural form for the same meaning throughout this relatively long period. In other words, he appeared to have a stable lexicon of gestures at his disposal. These findings suggest that it is possible for an individual to introduce standards of form within a communication system, although it appears to require a period of time, perhaps years, for such standards to evolve.

Note, however, that time alone is not sufficient for standards of form to appear in the manual modality. The deaf child's hearing sister, who interacted with him on a daily basis, produced gestures that were not only different from her deaf brother's gestures, but were also inconsistent within themselves. Her gestures thus lacked standards of form, despite the fact that she came into close contact with her brother's gesture system over a period of years. If there are standards in the sister's gestures, they are to be found only when gesture is evaluated in conjunction with the spoken system of which it is an integral part (see Goldin-Meadow, Alibali, & Church 1993 and McNeill 1992 for evidence that gesture and speech form an integrated system, and Goldin-Meadow 1993 and Singleton et al. 1993 for further discussion of how gestures change when they no longer accompany speech but themselves carry the full burden of communication).

5.2. LANGUAGE CREATION WITH AND WITHOUT A LEXICON. As we have argued, our data indicate that an individual, if given enough time, can introduce standards of form into a communication system within a single generation. Nevertheless, the gesture system of the deaf child in our study, although characterized by internal consistency, was a far less complex system than the sign languages passed down from generation to generation (see Goldin-Meadow & Mylander 1984, 1990b). What prevented the deaf child David from developing a gesture system as complex as ASL? The fact that David was only a child may have limited the complexity of his gesture system. However, children of David's age can certainly learn languages with a great deal more complexity than David introduced into his gesture system. Moreover, Simon, a deaf child no older than David, who received as input from his late-learner deaf parents only the lexicon of ASL and a very degraded model of ASL morphological structure, was found to have gone substantially beyond his impoverished input to develop a sign system with the complexity of ASL (Singleton & Newport 1993). Simon, however, had two linguistic advantages over David. First, Simon had a lexicon at his disposal, and the lexicon was, in fact, a product of historical change. Singleton & Newport (1993) argue that the outlines of the morphological system Simon developed were within the lexicon that he received as input. They argue that the outlines were blurred and degraded in the input, and that it was up to Simon to discover and enhance the system lurking in that fragmented input. Nevertheless, Simon did have the advantage of a system (albeit a degraded one) which was present and waiting to be discovered.

Parenthetically, it is worth noting that BOTH David and Simon had more sign-internal morphology than would be expected on the basis of Bickerton's 1988 account of creolizing situations in which children introduce structure into the relatively unsystematic pidgins spoken by their parents. The creoles described by Bickerton have an array of grammatical particles but, unlike David's and particularly Simon's communication systems, the creoles generally lack substantial inflectional and derivational morphology. This difference may arise because the iconic resemblances between form and meaning in the manual systems used by David and Simon facilitate reanalysis of these form-meaning pairings as morphological regularities. In contrast, the spoken pidgin vocabularies addressed to creolizing children are less likely to provide opportunities for such reanalysis.

A second linguistic advantage that Simon had over David is the fact that Simon and his parents SHARED the lexicon: they were both producers and receivers of the signs. Thus, Simon and his parents were free to go beyond iconicity, perhaps even sacrificing transparency for the sake of intralinguistic coherence. In contrast, as described above, David's family had chosen to educate him through an oral method, and their emphasis was on David's (minimal) verbal abilities. They did not treat David's gesture as though it were a language. In other words, they were not partners in the gestural communication that David used. In order to be understood, therefore, David's gestures needed to be iconic, i.e. transparently related to their referents.[5] An interesting question to pose is how far David could have gone in developing a complex communication system without a lexicon developed over generations, but with a willing communication partner who could have entered into and shared an arbitrary system with him. To date, we have not found a study situation that might allow us to address this question—for example, two deaf children inventing a gestural system with no input from a conventional sign language.

Because of the unusual circumstances in which he finds himself, David must

[5] Note that David's gesture was not absolutely limited by iconicity. There are instances in which the form David used was less mimetic than one might have expected. For example, he frequently depicted climbing a ladder, not as hands alternately grasping invisible rungs of a ladder while moving upward (as might be expected if the gesture was actually miming the act of climbing), but as hands alternately grasping in place, combined with a pointing hand moving upward. Despite instances of this sort, note that, in order to ensure that his communication partners could understand him, David could not afford to stray too far from the iconic roots of his gestures.

at least begin by inventing gestures that are iconic. Moreover, his circumstances do not allow him to stray too far from iconicity if his gesture system is to be understood. Note, however, that children who do not have to invent their language, but have only to learn it, appear to side-step iconicity altogether. Although sign languages are structurally comparable to spoken languages at both morphological and syntactic levels, they differ from spoken languages in having a relatively large number of lexical and morphological constructions that are iconically motivated. Linguists and psycholinguists specializing in ASL have argued that this iconicity is, in a sense, a red herring—it plays no role in the structural descriptions of the language, and it also plays no role in the way the language is processed (Klima & Bellugi 1979:88–124). Nevertheless, iconicity might provide a way into the formal linguistic system that could be exploited by the young language-learning child. However, in a longitudinal study of spontaneous signing (1981) and in a cross-sectional study in an experimental setting (1987), Meier has shown that the iconicity available in sign language is NOT exploited by the language-learning child (see also Orlansky & Bonvillian 1984 and Folven & Bonvillian 1991). These findings indicate that children will approach language as a formal system even if there is apparently (from an adult's perspective) an easier, iconic route open to them. Children appear to exploit iconicity only when it is necessary to do so, as in David's circumstances (cf. Meier 1987).

In sum, we have found that standards of form can be imposed on communication by an individual without the benefit of a language model passed down from generation to generation. However, our results suggest that a language-like system must serve the functions of communication for some period of time in order for such standards to evolve within the individual's system. Over the period of time that the home signer used his gestures, he apparently surveyed those gestures as a whole and treated them as a 'problem space' (cf. Karmiloff-Smith 1979) requiring systematization. It is the fact that each gesture was considered as a contrastive piece in a larger whole that distinguished the home signer, inventing gestures over a period of years, from the novice gesturer, inventing gestures on the spot. Thus, an individual (or at least a child), if given sufficient time, can not only invent a system of symbols for communication, but can invent one that is characterized by standards of well-formedness.

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