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What children contribute to language-learning

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There may be no greater testament to the resilience of language in humans than the observation that, when deprived of a language entirely, children will invent one nonetheless. Deaf children whose access to usable conventional linguistic input, signed or spoken, is severely limited develop gesture systems to communicate with the hearing individuals around them. The children's gestures resemble natural language in that they are structured at both sentence and word levels. Although the inclination to use gesture to communicate may be traceable to the fact that the deaf children's hearing parents (like all speakers) gesture as they talk, the deaf children themselves appear to be responsible for introducing language-like structure into their gestures. In particular, the structural properties found in the deaf children's gesture systems cannot be traced to the gestures that their hearing parents use with them, nor can they be traced to the way in which the parents respond to the children's gestures.

Language-learning is a phenomenon that engages both sides of the classic nature-nurture debate. On the one hand, the languages children hear have an obvious and profound impact on the languages they learn – a child who hears Georgian learns Georgian, not French or Swahili. The nurturing environment thus plays a massive role in language-learning. On the other hand, all human cultures, no matter how isolated, have language. Moreover, those languages are structured in strikingly similar ways and are used for very similar purposes. Thus it is within the nature of humans (and not dogs, cats, or

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even chimpanzees[1]) to develop language. The human child may bring certain abilities to language-learning that make the process possible.

How can we begin to discover the child's contribution to language-learning? The clearest picture of the child's role in the process can be obtained from situations in which children go beyond the input given to them. Children routinely exceed their input when they gain productive control of their language – when they can use language in ways they have never heard it used before. Consider, for example, the English-learning child who mistakenly produces "eated," an error according to adult norms and thus almost certainly not in the child's input. The error makes it clear that the child has abstracted a rule of English – add "ed" to the present tense form to generate the past tense form. The child has overgeneralized this rule to the irregular verb "eat."[2]

Children have the most room to improve upon their input when the language model they receive is degraded. For example, Newport and her colleagues[3,4] have described the language of deaf children whose deaf parents' signs provided an incomplete model of word-level structure in American Sign Language (ASL). The deaf children were exposed only to this imperfect model of ASL. Nevertheless, they developed sign languages with word-level structure comparable to the structure developed by other deaf children exposed to complete models of ASL. This example suggests that children can produce language output which exceeds their language input. Children appear to have the ability to organize the pieces of language they receive into a linguistic system governed by rules that are *not* used by the adults in their environment.

This review examines the communications of children who are, in effect, deprived of *all* usable linguistic input. I ask whether particular linguistic properties appear in a child's communication even if there is no model for them in the environment. The children described here are deaf with hearing losses so severe that they cannot naturally acquire oral language. In addition, these children are born to hearing parents who have not yet exposed them to a conventional sign language, such as ASL. Despite their lack of usable linguistic input, either signed or spoken, these deaf children develop gestural communication systems which share many – but not all – of the structural properties of the early linguistic systems of children exposed to established language models. The structural properties of early child language that are found in these gestural systems are precisely the properties that can be developed without benefit of linguistic input. Consequently, they can be taken to represent the child's contribution to the language-learning process.

Background on deafness and language-learning

Conventional sign languages, such as ASL or Italian Sign Language, are languages in the full sense of the word – they are structured at sentence, word, and sub-word levels, and they are used for the same functions as spoken languages – poetry, coersion, rhetoric, and so on. They are mutually unintelligible as are, for example, English and Italian. Deaf children exposed to a conventional sign language by their deaf parents acquire that language naturally. In other words, they progress through the same stages as hearing children acquiring a spoken language[5].

However, 90% of deaf children are not born to deaf parents. They are instead born to hearing parents who, quite naturally, speak to their children. Unfortunately, it is extremely uncommon for deaf children with severe to profound hearing losses to acquire the spoken language of their hearing parents 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 limited linguistic skills in speech[6]. 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 send their deaf children to "oral" schools in which sign systems are neither taught nor encouraged. These deaf children do not receive usable input in any conventional language system, signed or spoken. It is these children that I describe here.

My colleagues and I collected videotapes of 10 young deaf children ranging in age from 14 months to 4 years, 10 months. The children were deaf from birth with hearing losses so severe (70dB or greater bilateral hearing loss) that they had not acquired speech, even with intensive training in lip-reading. They occasionally produced single words but never combined those words into sentences. In addition, the children had not been exposed to a conventional sign language. Lacking a model for language, these deaf children might be expected to fail to communicate at all, or perhaps to communicate only in non-symbolic ways. This turns out not to be the case. All of the children used gesture to get their ideas across.

Deaf children born to hearing parents have long been known to spontaneously use gestures (referred to as "home signs") to communicate even when they have not been exposed to a conventional sign

language. Given a home environment in which family members communicate with each other through many different channels, it is not surprising that the deaf child would exploit the accessible modality (the manual modality) for the purposes of communication. The question, however, is whether the gestures that the deaf child uses to communicate are structured in language-like ways. In the next section, I describe the properties of the deaf child's gestures that can also be found in the communications of children learning language from conventional language models (signed or spoken). It is these shared properties that can be considered language-like, and it is these properties that human children appear to be able to develop without benefit of a language model.

The structural properties of the deaf child's gesture system

In theory, a child might effectively convey information in gesture by producing continuous and unsegmentable movements in mime-like fashion. For example, a child could elaborately pantomime a scene in which she is given a jar, twists off the lid, and blows a bubble in order to request the object and comment on its intended use. However, the deaf children did not behave like mimes. Rather, they produced discrete gestures that were often concatenated – their gestures resembled beads on a string rather than one, unsegmentable ribbon. For example, in relation to the bubbles, the child might extend her flat palm out to the listener and then point at her chest (to mean "give me"). Or, the child might point at the bubble jar and then produce a twisting motion in the air (to mean "twist the jar lid"). More elaborately, the child might raise her index finger to her lips while pretending to blow, followed by an O-shaped hand that moves away from her lips (to mean "blow the wand and then the bubble flies away").

All of the deaf children produced segmented gestures to communicate with the hearing individuals in their worlds. The "lexicon" of the gesture systems contained both pointing gestures and iconic gestures. Pointing gestures were used to index or indicate objects, people, places, and the like in the surroundings. Iconic gestures were stylized pantomimes whose forms captured the intended meaning of each gesture (*e.g.* a C-hand rotated in the air to indicate that someone was twisting open a jar). Gestures of this sort, particularly pointing gestures but also some iconic gestures, are produced by hearing children[7]. However, the deaf children's use of these gestures is unique in that their gestures fit into a structured *system*, while hearing children's gestures do not[8].

All natural languages, signed or spoken, have structure at more than one linguistic level (*e.g.* at the level of the sentence, word, and phoneme) and the deaf children's gesture systems are no exception. The gestures of the 10 deaf children whose systems were examined for sentence-level structure were found to have structure across gestures within a string,[9-11] and the gestures of the four deaf children whose systems were examined for word-level structure were found to have structure within a gesture as well as across them.[10]

Combining words into sentences: syntactic structure

The first important point to note is that each of the ten children combined their gestures into strings, and did so to fulfill a variety of the functions typically assumed by language – to make requests, comments, and queries, and even to describe events in the past and future[13]. The deaf children's gestures were frequently combined with one another to create new meanings. For example, a deaf child might combine a point at a grape with an "eat" gesture to comment on the fact that grapes can be eaten, and then later combine the "eat" gesture with a point at the experimenter to invite the experimenter to have lunch with the family.

Moreover, and equally important, the gesture strings that the deaf children produced functioned in a number of respects like the sentences of early child language. On this basis, these strings warrant the label "sentence." In particular, the children produced gesture strings characterized by two types of regularities.

(1) Regularities in terms of which elements were produced and deleted in a string. The children did not produce gestures for all of the possible thematic roles that could be conveyed within a sentence. However, they were not haphazard in their selection of which roles to convey in gesture. The children were more likely to produce a gesture for the patient (*e.g.* the cheese, in a sentence about a mouse eating cheese) than to produce a gesture for the actor (the mouse). In addition, the children produced gestures for the intransitive actor (*e.g.* the mouse, in a sentence about a mouse running to his hole) as often as they produced gestures for the patient (*e.g.* the eaten-cheese), and far more often than they produced gestures for the transitive actor (*e.g.* the eating-mouse). In this way, the likelihood of production served to systematically distinguish among thematic roles and thus mark those roles – an important function of grammatical devices. It is also worth noting that the particular pattern found in the deaf children's gestures – patients and intransitive actors marked in the same way and both different from transitive actors – is an analog of a structural case-marking pattern found

in naturally occurring human languages; in particular, ergative languages[4].

(2) Regularities in terms of where in the string each semantic element was produced. The children distinguished among the thematic roles they did express by placing the gesture for a given role in a particular position in a gesture string. The gestures the children produced within their strings were not produced in haphazard order but rather appeared to follow a small set of gesture order regularities. Gesture order regularities describe where the gesture for a particular thematic role is likely to appear in a gesture string. For example, in a string used to comment on the fact that the child intended to throw a toy grape, the child first produced a pointing gesture for the grape, the *patient*, before producing an iconic gesture for the *act*, throw. In general, the gesture for the object playing a patient role tended to *precede* the gesture for the act. As an example of a second gesture order, gestures for an object playing the role of recipient or goal tended to *follow* gestures for the act. For example, in a string used to request that an object be moved to a puzzle, the child produced an iconic gesture for the *act*, transfer (an iconic gesture), before producing a pointing gesture for the *recipient*, puzzle (a pointing gesture).

In addition, all of the children produced complex sentences, sentences that contain more than one proposition. For example, one child produced a "clap" iconic gesture, a point at himself, a "twist" gesture, a "blow" gesture, and a point at his mother to ask her to twist open the jar (proposition 1) and blow a bubble (proposition 2) so that he could clap it (proposition 3). Each child's gestures thus exhibited generative capability, an essential property of all natural languages.

Thus, the deaf children conjoined the gestures they produced into strings characterized by a number of structural properties found in all natural languages:

- the patterned production and deletion of semantic elements in the surface structure of a sentence.
- the patterned ordering of the semantic elements within a sentence.
- the concatenation of propositions within a sentence.

The children's gestures can therefore be said to conform to a syntax, albeit a simple one.

Decomposing the word: Morphological structure

The deaf children's gestures not only formed parts of longer sentence units, but the gestures themselves were made up of smaller

parts. For example, to request the experimenter to lay a penny down flat on a toy, one deaf child produced a downward motion with his hand shaped like an O. In itself this could be a global gesture presenting the shape and trajectory as an unanalysed whole. The experimenter pretended not to understand and, after several repetitions, the child factored the gesture into its components: first he statically held up the gesture for a round object (the O handshape) and then, quite deliberately and with his hand no longer in the O shape but exhibiting a flat palm, made the trajectory for downward movement. The original gesture was thus decomposed into two elements. This example implies the presence of a system of linguistic segments in which the complex meaning of "round-thing-moving-downward" is broken into components and the components combined into a gesture. Although the experimenter's feigned lack of understanding was undoubtedly important in getting the child to decompose his gesture at that particular moment, the point to be stressed here is that when the child did break his gesture into parts, those parts were elements of a wider system – one that accounted for virtually all of the gestures that this child produced.

This child thus had devised a morphological system in which each gesture was a complex of simpler gesture elements. Systematic compositionality of gestures within a system of contrasts is crucial evidence of segmentation and combination. As an example of how this child's gestures formed a system of contrasts, a CMedium handshape (the hand shaped in a C with the fingers 1–3 inches from the thumb) meant "handle an object 2–3 inches wide", and a Revolve motion meant "rotate around an axis." When combined, these two components created a gesture whose meaning was a composite of the two meanings – "rotate an object 2–3 inches wide" (*e.g.* twist a jar lid). When the same CMedium handshape was combined with a different motion, a Short Arc (meaning "reposition"), the resulting combination had a predictably different meaning – "change the position of an object 2–3 inches wide" (*e.g.* tilt a cup). As a result, the child's gestures can be said to conform to a framework or system of contrasts.

The gesture systems of four children have been analysed at this level, and all four children were found to produce gestures that could be characterized by paradigms of handshape and motion combinations. Each child was found to:

- use a limited set of discrete handshape and motion forms – the forms were categorical rather than continuous;
- consistently associate each handshape or motion form with a particular meaning (or set of meanings) throughout the corpus – each form was meaningful;

- produce most of the handshapes with more than one motion, and most of the motions with more than one handshape; that is, each handshape and motion was an independent and meaningful morpheme that could combine with other morphemes in the system to create larger meaningful units – the system was combinatorial.

Thus, the gestures that the deaf children combined into sentences were themselves composed of smaller handshape and motion parts. These gestures can therefore be said to conform to a morphology, albeit a simple one.

The child is mother to the gesture

The deaf children in these studies were found to elaborate gestural communication systems characterized by language-like properties without benefit of a conventional language model. They therefore did not learn their gestural systems in the traditional sense of the word. Nevertheless, the children were exposed to the spontaneous gestures that their hearing parents used when speaking to them, as are hearing children of all hearing parents[15]. These gestures could conceivably have served as input to the children's gestural systems, and therefore must be the backgound against which their gestural accomplishments are evaluated.

Is there syntactic structure in the mother's gestures?

In an analysis of parental input to sentence-level structure in six of the deaf children, we found that, although the deaf children's hearing mothers did indeed gesture, they produced relatively few gesture strings. Moreover, the few gesture strings the mothers did produce did not show the same structural regularities as their children's. The mothers showed no reliable gesture order patterns in their gesture strings. Moreover, the patterns of production and deletion found in the mothers' gesture strings were different from the patterns found in the children's strings. Finally, the mothers began conveying complex gesture sentences later in the study than their children, and produced proportionately fewer complex sentences than their children. Thus, the mothers' gestures did not provide a good model for the syntactic structure found in the deaf children's gesture systems[11,16].

Is there morphological structure in the mother's gestures?

To determine whether the mother's gestures offered a model for the morphological structure found in the deaf child's gestures, the gestures

that each mother produced were coded within the framework of the morphological system developed by her child. Each mother was found to use her gestures in a more restricted way than her child, omitting many of the morphemes that the child produced (or using the ones that she did produce more narrowly than the child), and omitting completely many of the handshape/motion combinations that the child produced. In addition, while there was good evidence that the gestures of each deaf child could be characterized in terms of handshape and motion components which mapped onto a variety of related objects and a variety of related actions, respectively, there was no evidence that the mothers ever went beyond mapping gestures as wholes onto entire events – that is, the mother's gestures did not appear to be organized in relation to one another to form a system of contrasts. Finally, when the mothers' gestures were analysed with the same procedures used to analyse the children's gestures (that is, when the mother's gestures were treated as a system unto itself), the resulting system for each mother did not capture her child's gestures well at all.[12]

Maternal responsiveness to the child's gestures

The structural properties of the deaf children's gesture systems were *not* patterned after the spontaneous gestures that their hearing parents used with them. This fact suggests that the children themselves may have played a large role in creating those structural properties. However, it is possible that the structure in the children's gesture systems came not from the child but from other non-linguistic aspects of the child's environment. For example, it is possible that, by responding with either comprehension or non-comprehension to their children's gestures, the hearing mothers of these deaf children might have (perhaps inadvertantly) shaped the structure of those gestures.

To explore this possibility, we divided each child's gesture strings into strings that followed the child's own preferred orders and strings that were exceptions to those orders. We then determined how often the child's hearing mother gave relevant and comprehending reactions to both types of strings. We found that the mothers responded with comprehension to approximately half of each child's gesture strings – whether or not those strings followed the child's preferred orders. In other words, the mothers were just as likely to understand the children's ill-formed strings as their well-formed strings, suggesting that these particular patterns of parental responsivity did not shape the orders (or the patterns of production and deletion) that the children developed in their gesture systems[11,16].

There seems little doubt, however, that comprehensibility determined the form of the deaf children's gestures at a general level. The children's gestures were for the most part iconic, with gesture forms transparently related to the intended meanings. Indeed, the overall iconicity of the children's gestures may have made producing the gestures in a consistent order superfluous – a mother could easily figure out that her child was describing apple-eating whether the child pointed at the apple before producing an "eat" gesture, or produced the "eat" gesture before pointing at the apple. Thus, although the children's gestures were quite comprehensible to the hearing individuals around them, the structural details of each child's gesture system did not appear to be shaped by the way in which the mothers responded to those gestures.

The robustness of the gesture systems across cross-cultural variation

However, parent–child interaction may affect child communication in other, more subtle ways. For example, Bruner[17] has suggested that the structure of joint activity between mother and child can exert a powerful influence on the structure of the child's communication. We embarked on a cross-cultural study to explore the robustness of the phenomenon of gesture creation, and to determine the extent to which the gesture system is a product of the way in which mothers and children jointly interact in their culture. We observed deaf children of hearing parents in a second culture – a Chinese culture – which has been found to differ from American culture in its child-rearing practices[18,19]. Our own studies of the interaction between hearing mothers and their *deaf* children in Chinese and American families have confirmed these differences[20]. Thus, we now ask whether, despite these differences, Chinese deaf children use gesture to communicate and, if so, whether their gestures are structured in ways similar to the American deaf children's gestures.

We found that, not only did the Chinese deaf children gesture, but the structure of their gesture sentences was comparable to the American deaf children's[21]. Both the Chinese and American children distinguished patients from actors when describing actions that affect objects (*e.g.* eating). For example, the children were more likely to produce a gesture for the patient (cheese) than the transitive actor (mouse), and tended to produce the patient gesture in first position of a two-gesture sentence ("cheese-eat"). In addition, the children treated actors involved in actions that do not affect objects (*e.g.* running) like patients. They produced gestures for the running-

mouse as often as for the eaten-cheese (and more often than gestures for the eating-mouse) and they put gestures for the running-mouse in first position of their sentences. Children's gestures in *both* cultures conformed to this pattern – an ergative pattern, as described above. This pattern is found in some spoken languages but, importantly, neither Mandarin nor English.

In addition, children in both cultures produced a large proportion of complex sentences, each containing more than one proposition. The children differed primarily in their use of culturally-bound emblematic gestures. For example, the Chinese mothers used a finger brushed across the cheek to mean "shame." Their deaf children also used this form, which was not found in any American child's (or mother's) gestures. We have not yet examined the more detailed aspects of morphologic structure in the Chinese children's gestures.

As described above, the American mothers' gestures did *not* resemble their children's. While the children frequently produced strings of gestures, their mothers did not; even when the mothers did conjoin gestures within a single string, the gestures in the strings did not follow the same orders or production patterns as their children's gestures. Indeed, American children's gestures had more in common with Chinese children's gestures than with their own mothers'. American *children* thus appear to be responsible for the structural aspects of their systems.

In contrast, the Chinese mothers' gestures did resemble their children's, at least in part. The particular gesture orders that the Chinese mothers used in their gesture sentences were comparable to those found in their children's gesture sentences, although their patterns of production and deletion were not. The Chinese children may, therefore, have learned some of the segments of their gesture systems from their mothers. However, given that the Chinese and American children's gestures appear to follow the same patterns, it is more likely that the Chinese mothers learned their gesture orders from their children. If so, we then need to ask why the Chinese (but not the American) mothers copied gesture patterns from their deaf children. The answer might involve cultural differences in attitudes toward children's communications, or the languages themselves (it may be easier to produce strings of gestures while speaking Mandarin than while speaking English). Whatever the reason, the fact remains that American children took the lead in creating their gesture systems, a lead their mothers did not follow.

Given the differences in the worlds that the deaf children in these two cultures experienced, the similarities found in the spontaneous gesture systems developed by these children provide preliminary

evidence for the non-effects of mother–child interaction patterns on the development of these linguistic properties. We thus have evidence for the resilience of these aspects of language in the face of cultural variation.

Conclusions

We have found that a number of linguistic properties appear to be essential to symbolic human communication, so essential that a child can reinvent them even if there is no explicit model for them in the linguistic environment. These findings suggest that children may bring constraints to the communication situation, constraints that facilitate their acquisition of these particular properties.

However, the studies described here do not identify (nor do they assume) a particular cause for the constraints that guide human language development. Constraints on development are often attributed to genetic causes[22]. However, constraints can be environmental as well. Gottlieb[23] has shown that exposure to a stimulus at one point in development not only makes the organism particularly susceptible to that stimulus at later points, but it also makes the organism *less* susceptible to other stimuli. In other words, it buffers the organism against certain stimuli, thereby narrowing the range of possibilities open to the organism. The properties that we have identified as resilient in human communication may, in the end, be an inevitable consequence of the developing human mind forced to grapple with the task of shared symbolic communication[24].

Our studies provide an empirical process by which the child's contributions to language-learning can be identified. The findings can then serve as a framework within which developmental causes can be explored. In this way, the findings inform the search for the biological and cultural foundations of the language-learning process.

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