What language creation in the manual modality tells us about the foundations of language[1]

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Abstract

Universal Grammar offers a set of hypotheses about the biases children bring to language-learning. But testing these hypotheses is difficult, particularly if we look only at language-learning under typical circumstances. Children are influenced by the linguistic input to which they are exposed at the earliest stages of language-learning. Their biases will therefore be obscured by the input they receive. A clearer view of the child's preparation for language comes from observing children who are not exposed to linguistic input. Deaf children whose hearing losses prevent them from learning the spoken language that surrounds them, and whose hearing parents have not yet exposed them to sign language, nevertheless communicate with the hearing individuals in their worlds and use gestures, called homesigns*, to do so. This article explores which properties of Universal Grammar can be found in the deaf children's homesign systems, and thus tests linguistic theory against acquisition data.*

1. The implications of Universal Grammar for language learning

A case can be made for some degree of biological specialization for language learning in humans. The problem is figuring out what this specialization looks like. Jackendoff (2002) sees his book as providing a version of Universal Grammar that is sufficient to explain language learning and that strives for biological realism – in a sense, a set of hypotheses about what children bring to the

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language-learning situation. As Jackendoff notes, innateness is not about how language is processed online; it is about how language is acquired, an idea first introduced by Chomsky (1965). To put this idea and, in particular, Jackendoff's psychology-friendly version of Universal Grammar to the ultimate test, we have to look at language-learners.

But what predictions does Universal Grammar make about language-learning? Jackendoff argues that not all of the features of Universal Grammar need to appear in every language. He likens Universal Grammar to a toolkit – languages can pick and choose which tools in the kit they will use. What then should we expect of language-learners? Should they display all of the properties of Universal Grammar even if those properties are not instantiated in the language they are learning? We know that the language model to which a child is exposed has an immediate impact on the language that the child learns – in many respects, children appear to be native-speakers from the earliest stages of language development. Failure to find a particular property of Universal Grammar in a child's repertoire could therefore be a sign that the child has already figured out which tools in the kit her language does and doesn't use – and not evidence that the property does not belong in Universal Grammar. Thus, it is not easy to evaluate hypotheses about Universal Grammar using data from children who are learning language under typical circumstances.

We can, however, turn to children who are not experiencing typical language-learning circumstances. Indeed, Jackendoff suggests that the most striking evidence for a prespecified skeleton for language can be found when children create language where there was none before. In this article, I consider one such case – deaf children whose hearing losses are so severe that they cannot acquire the spoken language that surrounds them, and whose hearing parents have not yet exposed them to a conventional sign language. Children in this situation fashion a system of "homesigns" that they use to communicate with the hearing people in their worlds. If Universal Grammar is the base that permits learning to proceed when a language model is present, it should also be the base around which language is constructed when no model is present – and its properties should be particularly easy to see because they will not have been influenced by any particular current-day language.

Homesign is, of course, relevant to questions about the foundations of language only if languages that are based in the manual modality are languages in the full sense of the word. I therefore begin by establishing this point and its implications for language-learning.

2. Sign languages are languages in the full sense of the word

Deaf individuals across the globe use sign languages as their primary means of communication. These sign languages not only assume all of the functions served by spoken languages, but they also display the structural properties characteristic of spoken languages. Sign languages are autonomous systems that are not based on the spoken languages of hearing cultures (Klima and Bellugi 1979). Thus, the structure of ASL is distinct from the structure of English. Indeed, the structure of *American* Sign Language is distinct from the structure of *British* Sign Language – an observation that dramatically underscores the point that sign languages are not derivative from spoken languages. The fact that sign languages are not borrowed from spoken languages makes it that much more striking that they are structurally similar to spoken languages.

Speech segments and linearizes meaning. What might be an instantaneous thought is divided up and strung out through time. A single event must be conveyed in segments, and these segments are organized into a hierarchically structured string of words. Despite the fact that signs have the potential to represent meaning globally and simultaneously, segmentation is also an essential characteristic of sign languages. As in spoken languages, there are segments at each of the levels important to language and rules dictating how those segments can be combined – at the sentence level (i.e., syntactic structure, e.g., Liddell 1980), at the word/sign level (i.e., morphological structure, e.g., Klima and Bellugi 1979), and at the level of meaningless units (i.e., "phonological" structure, e.g., Liddell and Johnson 1986).

The fact that sign languages look so much like spoken languages underscores an important point – language cannot be a by-product of articulatory/acoustic exchanges. Even if articulatory/acoustic pressures led to grammatical structure over evolutionary time, the structure that current-day languages assume cannot be a simple reflection of these pressures simply because grammatical structure in sign languages are not beholden to the same pressures. Sign languages are processed by hand and eye rather than mouth and ear. Whatever explanations we propose to account for language must acknowledge this fact.

Sign languages look like natural languages not only in terms of structure but also in terms of acquisition. Deaf children born to deaf parents and exposed to sign language from birth learn that language as naturally as hearing children learn the spoken language to which they are exposed (Newport and Meier 1985; Lillo-Martin 1999). Children who lack the ability to hear are thus completely intact when it comes to language-learning and will demonstrate that ability if exposed to usable linguistic input. However, most deaf children are born, not to deaf parents, but to hearing parents who are unlikely to know a conventional sign language. If the children's hearing losses are severe, those children are typically unable to learn the spoken language that their parents speak to them, even with hearing aids and intensive instruction (Mayberry 1992). If, in addition, the children's hearing parents do not choose to expose them to sign language, the children are in the unusual position of lacking usable input from a conventional language. Their language-learning skills are intact, but they have no language to apply those skills to.

What should we expect from children in this situation? A language model might be essential to activate whatever skills children bring to language-learning. If so, deaf children born to hearing parents and not exposed to conventional sign language ought not communicate in language-like ways. If, however, these deaf children manage to communicate despite their lack of linguistic input, we should be able to get a clear picture of the skills that all children bring to language-learning from the communication systems that the deaf children develop. The question I address in the next section is whether these home-made communication systems display the properties that Jackendoff considers part of Universal Grammar.

3. Does homesign exhibit properties of Universal Grammar?

One of the frustrations that psychologists experience when trying to extend linguistic theory to psychological problems is that it is difficult to find a list of the properties of Universal Grammar. It's clear what Universal Grammar is in principle, but what counts as Universal Grammar? Indeed, even in Jackendoff's *Foundations of Language* (2002), it is difficult to find a concise description of the contents of Universal Grammar. The closest thing to a list of properties that we might look for in a newly created language is the list of evolutionary steps that Jackendoff assumes language took to arrive at its modern day form (Figure 8.1, p. 238). The skills that are responsible for these steps are assumed to be part of the toolkit that comprises Universal Grammar. I therefore consider whether there is evidence for these skills in the homesign systems generated by children who lack exposure to a modern day language.

I describe here data gathered from ten deaf children of hearing parents in America (either Philadephia or Chicago and their surrounds) and four in Taipei, Taiwan. The children were videotaped in their homes every few months interacting with their primary caregivers (the mother in every case) or with an experimenter. The children were observed for varying periods of time, the youngest child at 1 year, 4 months and the oldest at 5 years, 11 months (see Goldin-Meadow 2003a for details).

3.1. Symbols

Do the deaf children display a voluntary use of discrete symbolic signals, gestures, in this instance? The answer is unequivocally "yes". The children produce gestures for the purpose of communicating with the hearing individuals in their worlds, and those gestures, rather than being mime-like displays, are discrete units, each of which conveys a particular meaning. Moreover, the gestures are non-situation-specific – a *twist* gesture can be used to request someone to twist open a jar, to indicate that a jar has been twisted open, to comment that a jar cannot be twisted open, to tell a story about twisting open a jar that is not present in the room. In other words, the children's gestures are not tied to a particular context, nor are they even tied to the here-and-now (Morford and Goldin-Meadow 1997). Not only do the children invent symbols, but the store of symbols seems to be unlimited and stable over developmental time (Goldin-Meadow et al. 1994). In this sense, the children's gestures differ from the co-speech gestures hearing speakers produce as they talk (Goldin-Meadow 2003b) and thus warrant the label *sign*.

3.2. A generative system for single symbols

Modern languages (both signed and spoken) build up words combinatorially from a repertoire of a few dozen smaller meaningless units. We have not yet been able to figure out how to ask whether the deaf children's signs are systematic combinations of meaningless parts; that is, whether they have a phonology.[2] However, we have determined that the children's signs are made up of *meaningful* parts; that is, they have a morphology (Goldin-Meadow et al. 1995). The children could have faithfully reproduced the actions that they perform in the world in their signs. They could have, for example, created signs that capture the difference between holding a balloon string and holding an umbrella. But they don't. Instead, the children's signs are composed of a limited set of handshape forms, each standing for a class of objects, and a limited set of motion forms, each standing for a class of actions. These handshape and motion components combine freely to create signs, and the meanings of these signs are predictable from the meanings of their component parts. For example, an *OTouch* handshape form combined with a *Revolve* motion form means "rotate an object < 2 inches wide around an axis", a meaning that can be transpar-

2. As described in this section, we have isolated a set of handshape and motion components that would be good candidates for a phonological analysis of the homesign systems. Future work is needed to determine whether these components function as phonemes do in natural conventional languages.

ently derived from the meanings of its two component parts (*OTouch* = handle an object < 2 inches wide; *Revolve* = rotate around an axis).

Importantly in terms of arguing that there really is a system underlying the children's signs, the vast majority of signs that each deaf child produces conforms to the morphological description for that child and the description can be used to predict new signs that the child produces. Interestingly, it is much more difficult to impose a coherent morphological description that can account for the gestures that hearing speakers produce (Goldin-Meadow et al. 1995), suggesting that morphological structure is not an inevitable outgrowth of the manual modality but is instead a characteristic that the deaf children impose on their communication systems. Thus, the signs that the deaf children create form a simple morphology, one that is akin to the morphologies found in conventional sign languages. It is clear that the children's signs can be decomposed into parts. What remains uncertain is whether those parts can be further decomposed into meaningless segments equivalent to the phonetic-phonemic levels of spoken language.

3.3. Concatenating symbols to build larger utterances and using linear position to signal semantic relations

The deaf children combine their signs into larger wholes. The motoric "boundary markers" that carve out these wholes – pauses and/or relaxation of the hands – are the same markers used to signal sentence boundaries in conventional sign languages and seem in many ways equivalent to the intonational markers that mark sentence boundaries in speech (e.g., declination). When we examine the "sentences" that arise from applying these markers to the deaf children's homesigns, we discover that the meanings of these combinations reflect the meanings of the constituent symbols. For example, one deaf child pointed at his dog (who was not barking at the time), pointed outside, and then signed *bark* right after the milkman arrived. He had combined a string of signs to tell his mother that if the dog stayed outside, it would bark (presumably in response to the milkman's arrival).

According to Jackendoff, the first step in building a sentence is to concatenate two or more symbols into a single string with the connection among the symbols dictated by context. However, the deaf children go beyond this stage, using linear position to indicate who does what to whom (Feldman et al. 1978). Surprisingly, all of the deaf children (even those in China) use the same particular linear orders in their sign sentences despite the fact that each child is developing his or her system alone without contact with other deaf children (Goldin-Meadow and Mylander 1998). The children tend to produce signs for patients in the first position of their sign sentences, before signs for verbs (*cheese–eat*) and before signs for endpoints or, in my terms, recipients (*cheese–table*).[3] They also produce signs for verbs before signs for recipients (*give–table*). In addition, they produce signs for intransitive actors before signs for verbs (*mouse-run*); see also the example presented above, *dog* (intransitive actor)–*outside–bark* (act).[4] Although these are not intricate rules, they do serve the function of indicating who is doing what to whom, and thus represent a step beyond concatenation without any internal structure.

The properties described thus far are those that Jackendoff ascribes to protolanguage – the first step in the evolution of language. But deaf children inventing their own language go beyond protolanguage.

3.4. Going beyond linear position to signal semantic relations

3.4.1. Production probability reflects underlying predicate frames. The deaf children not only use linear position to structure their sign sentences, but they also use the systematic production and deletion of semantic elements – *production probability*. Production probability provides us with evidence that the children's sign sentences are structured around predicate frames.

Sentences in natural language are claimed to be organized around verbs. The verb conveys the action which determines the thematic roles or arguments (θ-roles) that underlie the sentence. Do frameworks of this sort underlie the deaf children's sign sentences? The deaf children rarely produce all of the arguments that belong to a predicate in a single sentence.[5] What then makes us think that the entire predicate frame underlies a sentence? Is there evidence, for example, that the recipient and actor arguments underlie the sign sentence *cookie–give* even though the patient *cookie* and the act *give* are the only elements that appear in the sentence? Yes. The evidence comes from production probability. Production probability is the likelihood that an argument will be

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3. I use the term "recipient" to refer to both animate and inanimate endpoints of a change-of-location motion simply because the deaf children do not appear to distinguish between the two in their homesigns. Note also that I use the term *verb*. It is possible that the gestures I'm calling verbs do not reflect a grammatical category but rather a semantic category; that is, that they are better described as *action* terms. I provide evidence suggesting that gestures of this sort do indeed constitute verbs rather than names for actions in Section 3.7 (see also Goldin-Meadow et al. 1994).
4. The *outside* sign indicates the place where the activity was occurring. The children did not produce a sufficient number of *place* signs for us to determine whether the signs occupied a consistent position in the children's sign sentences.
5. In fact, children who are exposed to a language model also go through an early stage during which they produce no more than two words per sentence (e.g., Bloom 1970). Interestingly, at this stage, children tend to show the same ergative pattern of production and omission found in the deaf children (see Section 3.4.2), even when the language they are learning is not ergative (Zheng and Goldin-Meadow 2002).

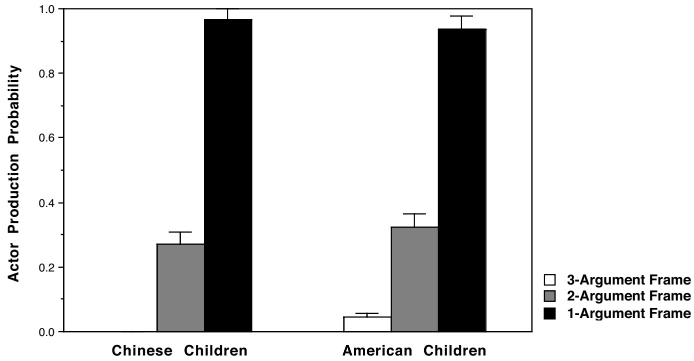

Figure 1. The production of signs for semantic elements in a sentence depends on the predicate frame underlying that sentence. The figure displays the likelihood that the Chinese and American deaf children will produce a sign for an actor in a 2-sign sentence as a function of the predicate frame underlying that sentence. Children are more likely to produce actors in sentences with a 1-argument than a 2-argument predicate frame, and in sentences with 2-argument than a 3-argument predicate frame, simply because there is less "competition" for the two slots in surface structure when the underlying frame contains fewer units and thus offers fewer candidates for those slots. Errors bars reflect standard errors.

signed when it can be. Although the children could leave elements out of their sign sentences haphazardly, in fact they are quite systematic in how often they omit and produce signs for various arguments in different predicate frames.

Take the actor as an example. If we are correct in attributing predicate frames to the deaf children's sign sentences, the actor in a *give* predicate should be signed *less* often than the actor in an *eat* predicate simply because there is more competition for slots in a 3-argument *give* predicate than in a 2-argument *eat* predicate. The *giver* has to compete with the *act,* the *given* and the *givee*. The *eater* has to compete only with the *act* and the *eaten*. This is the pattern we find (see Figure 1). Both the American and Chinese deaf children are *less* likely to produce an actor in a sentence with a 3-argument underlying predicate frame (e.g., the *giver*, white bars) than an actor in a sentence with a 2-argument underlying predicate frame (e.g., the *eater*, gray bars). Following the same logic, an *eater* should be signed *less* often than a *dancer* (black bars), and indeed it is in both the American and Chinese children.

In general, what we see in Figure 1 is that production probability *decreases* systematically as the number of arguments in the underlying predicate frame *increases* from 1 to 2 to 3 (and it does so for each of the children, Goldin-

Meadow 2003a). Importantly, we see the same pattern for patients: The children are *less* likely to produce a sign for a *given* apple than for an *eaten* apple simply because there is more competition for slots in a 3-argument *give* predicate than in a 2-argument *eat* predicate; that is, they are more likely to sign *apple–eat* than *apple–give*, signing instead *give–palm* to indicate that mother should transfer the apple to the palm of the child's hand.

Importantly, it is the underlying predicate frame that dictates actor production probability in the deaf children's sign sentences, not how easy it is to guess from context who the actor of a sentence is. If predictability in context were the key, 1st and 2nd person actors should be omitted regardless of underlying predicate frame because their identities can be easily guessed in context (both persons are on the scene); and 3rd person actors should be signed quite often regardless of underlying predicate frame because they are less easily guessed from context. However, the production probability patterns seen in Figure 1 hold for 1st, 2nd, and 3rd person actors when each is analyzed separately. The predicate frame underlying a sentence is indeed an essential factor in determining how often an actor will be signed in that sentence.

This is an important result. Tomasello (2000) suggests that the process of learning predicate frames is completely data-driven – that children learn from linguistic input which arguments are associated with a verb on a verb-by-verb basis. The implicit assumption is that, without linguistic input, children would not organize their verbs around predicate frames. But our data suggest otherwise, as do experimental data gathered from young infants. Pre-linguistic infants expect actors, patients, and recipients to be involved in actions like giving, and are surprised if a toy bear transferred between two individuals disappears from the event. Importantly, they are indifferent to that bear disappearing from an event in which the same two individuals, one holding a bear, are hugging one other, suggesting that the infants expect only two arguments – an actor and a patient – to be involved in actions like hugging (Gordon 2004). Children seem to come to language-learning with at least some predicate frames in mind. They expect (perhaps on the basis of observations of the real world, but see Gleitman et al. 2005 for the problems inherent in this view) that symbols referring to transferring objects will be associated with 3 arguments (actors, patients, recipients) and symbols referring to acting on objects will be associated with 2 arguments (actors, patients). All a child learning English need do is figure out that "give" is a verb of the first kind, and "hug" is a verb of the second kind. Rather than requiring linguistic input for their construction, these "starter set" predicate frames can help children make sense of the linguistic input they receive. Note that "syntactic bootstrapping" proposals (e.g., Gleitman 1990; Lidz and Gleitman 2004) are built and justified in large measure on the fact that infants who have not been exposed to language can nevertheless construct predicate frames. It is these frames that children bring to language-learning and that get the ball rolling, allowing children to interpret and use the predicate structures they hear to learn the details of the language they are learning.

The predicate frames that the deaf children in our study have constructed parallel non-linguistic representations of the events these verbs encode. But note that, although these frames may derive from non-linguistic representations, they truly are constructions on the part of the child. There are many aspects of a transferring-object event that could have been – but are not – part of the deaf child's predicate frame (nor are they part of the predicate frame for transfer verbs in any natural language) – the original location that the object was in before it was moved, the locale in which the moving event took place, the time at which the event took place, and so on. The interesting point is that, even without benefit of linguistic input and thus without learning words like "give", children take three particular arguments (actor, patient, and recipient) to be essential to communicating about transferring-object events. Whether these three elements also have priority in other cognitive tasks that do not involve communication (i.e., whether they are specific to language) is not yet known, and bears on how task-specific predicate frames of this sort are. The point to stress here is that these child-constructed predicate frames influence the form of the children's sign sentences and, in this sense, are relevant to language-learning.

3.4.2. Production probability signals who does what to whom. Production probability not only reflects underlying predicate structures but it also signals who does what to whom. Thus, the deaf children's sign systems have taken a step beyond protolanguage which indicates who does what to whom exclusively by linear order. Unlike the above analysis where we compared production probability of a given role (e.g., the actor) across different underlying predicate frames, in this analysis we compare production probability of different roles (e.g., the actor vs. the patient) in predicate frames of the same size. If the children were to haphazardly produce signs for the thematic roles associated with a given predicate, they should produce signs for patients equally as often as they produce signs for actors in, for example, sentences about eating. We find, however, that here again the children are not random in their production of signs for thematic roles – in fact, likelihood of production distinguishes thematic roles (Goldin-Meadow and Mylander 1998). Both the American and Chinese deaf children are more likely to produce a sign for the patient (e.g., the eaten cheese) in a sentence about eating than to produce a sign for the actor (e.g., the eating mouse).

Two points are worth noting. First, the children's production probability patterns convey probabilistic information about who is the doer and the done-to in a two-sign sentence. If, for example, a deaf child produces the sign sentence "boy hit", we would infer that the boy is more likely to be the hittee (patient) in the scene than the hitter (actor) precisely because the deaf children tend to produce signs for patients rather than transitive actors. Indeed, languages around the globe tend to follow a similar pattern. For example, in languages where only a single argument is produced along with the verb, that argument tends to be the patient rather than the actor in transitive sentences (DuBois 1987). Second, the deaf children's particular production probability pattern tends to result in two-sign sentences that preserve the unity of the predicate – that is, patient + act transitive sentences (akin to OV in conventional systems) are more frequent in the deaf children's signs than actor + act transitive sentences (akin to SV in conventional systems).

Actors appear not only in transitive sentences with 2-argument predicate frames (*mouse*, eat, cheese) but also in *intransitive* sentences with 2-argument predicate frames (*mouse*, go, hole). How do the deaf children treat intransitive actors, the figure that moves itself to a new location? Both American and Chinese children produce signs for the intransitive actor as often as they produce signs for the patient, and far more often than they produce signs for the transitive actor (Goldin-Meadow and Mylander 1998). This production probability pattern is reminiscent of case-marking patterns found in ergative languages (Dixon 1979) – intransitive actors resemble patients and both are distinguished from transitive actors in terms of production probability.

It is important to note that the deaf children really do seem to be marking thematic role, and not just producing signs for the most salient or most informative element in the context. An alternative possibility is that the children produce signs for elements that are new to the discourse, and that intransitive actors and patients are more likely than transitive actors to be new (DuBois 1987). If the novelty of a semantic element were responsible for how often that element is signed, we would expect production probability to be high for all new elements (regardless of role) and low for all old elements (again, regardless of role). However, both American and Chinese children produce signs for transitive actors less often than they produce them for intransitive actors or patients, whether those elements are new (top graph, Figure 2) or old (bottom graph). Thus, we find an ergative production probability pattern for new elements when analyzed on their own, as well as for old elements when analyzed on their own. Thematic role, rather than novelty, seems to determine how often an element is signed. It is, of course, possible that the human mind considers all objects that undergo action (the actions produced by another in a transitive sentence or the actions produced by the self in an intransitive sentence) to be salient. But note that, under this view, it is not at all clear what is meant by salience beyond using it as another name for patients and intransitive actors (particularly since, as Figure 2 indicates, salience cannot refer to new vs. old information).

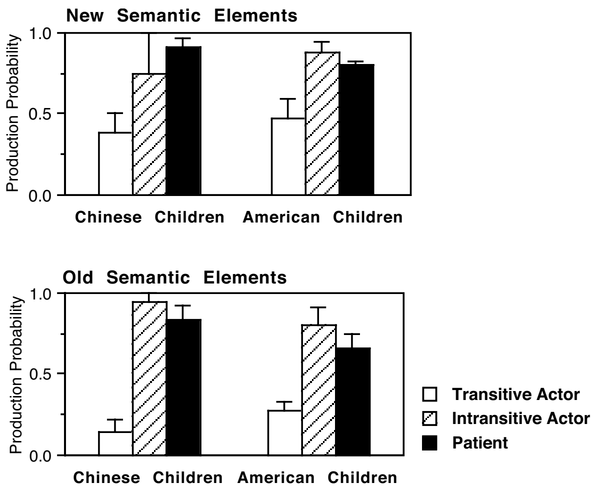

Figure 2. The deaf children follow an ergative pattern whether they are signing about new or old semantic elements. The figure displays the likelihood that American and Chinese deaf children will produce signs for transitive actors, intransitive actors, or patients when those elements are new (top) or old (bottom) to the discourse. The ergative pattern is evident in both graphs, suggesting that ergative structure at the sentence level is independent of the newness of the elements in discourse. Error bars reflect standard errors

3.4.3. Inflection signals who does what to whom. In addition to linear position and production probability, the deaf children use one other device to signal who does what to whom. Signs can be produced in neutral space (at chest level) or displaced toward objects or spaces in the real world. We call these displacements *inflections*, following the sign language literature (Padden 1983). In ASL signs can be displaced to agree with their noun arguments. For example, the sign *give* is moved from the signer to the addressee to mean "I give to you" but from the addressee to the signer to mean "You give to me." In ASL, it is possible for a verb to agree with a noun argument that refers to a non-present object or person. To say "I give to George" when George is not in the room, the signer locates the non-present George in signing space and moves the sign *give* from the signer toward that space. The deaf children also inflect their signs for non-present objects. Occasionally they do so by displacing their signs toward a space that has been set up to stand for a non-present object. However, more often they displace their signs toward a present object that resembles the intended non-present object (e.g., signing *twist* near an empty bubble jar to indicate that the twisting should be done on the full bubble jar in the next room; Butcher et al. 1991)

The deaf children tend to displace their signs toward objects that are acted upon and thus use their inflections to signal patients. For example, displacing a *twist* sign toward a jar signals that the jar (or one like it) is the object to be acted upon (Goldin-Meadow et al. 1994). As we might expect since these inflections are part of the verb, they are sensitive to underlying predicate frames – 3-argument verbs are more likely to be inflected than 2-argument verbs. Indeed, inflection appears to be obligatory in 3-argument verbs but optional in 2-argument verbs where it trades off with lexicalization (verbs in sentences containing an independent sign for the patient are less likely to be inflected than verbs in sentences that do not contain a sign for the patient, Goldin-Meadow et al. 1994). The deaf children have clearly moved beyond marking who does what to whom by context alone.

3.5. Phrase structure and recursion

Jackendoff notes that a major advance occurs when patterns are formulated not in terms of words but in terms of phrases, where a collection of words functions as an elaborated version of a single word. This is a crucial design feature of modern language, one that makes possible expressions with hierarchical embedding. We find some sentences in the deaf children's signs where a phrase seems to have substituted for a single sign. For example, rather than sign *penny–me* to request that the experimenter give him a penny, the child signs *round–penny–me* where the sign *round* modifies *penny*; both signs occupy the patient slot in the sentence and, in this sense, function like a phrase. But at present we do not have enough instances of this type to be certain this is a systematic pattern.

There is evidence, however, that the children combine more than one proposition within the bounds of a single sentence and that the two propositions are subordinate to a higher node. A complex sentence is the conjunction of two propositions. The frame underlying such a sentence ought to reflect this conjunction – it ought to be the sum of the predicate frames for the two propositions. For example, a sentence about a soldier beating a drum (proposition 1) and a cowboy sipping a straw (proposition 2) ought to have an underlying frame of 6 units – 2 predicates (beat, sip), 2 actors (soldier, cowboy), and 2 patients (drum, straw). If the deaf children's complex sentences are structured at an underlying level as their simple sentences are, we ought to see precisely the same pattern in their complex sentences as we saw in their simple sentences – that is, we should see a systematic decrease in, say, actor production probability as the number of units in the conjoined predicate frames increases.

This is precisely the pattern we find (Figure 3). There is, however, one caveat. We find this systematic relation *only if* we take into account whether a semantic element is shared across propositions. Sometimes when two propositions are conjoined, one element is found in both propositions. For example, in the English sentence "Elaine cut apples and Mike ate apples," *apples* is shared across the two propositions (the second *apples* could be replaced by *them* and the pronoun would then mark the fact that the element is shared). The deaf children's complex sentences exhibit this type of redundancy, and at approximately the same rate as children learning language from conventional models (Goldin-Meadow 1987:117). For example, one child produces *climb–sleep–horse* to comment on the fact that the horse climbs the house (proposition 1) and the horse sleeps (proposition 2). There are 3 units underlying the first proposition (actor, act, object – *horse, climb, house*) and 2 in the second (actor, act – *horse, sleep*), but one of those units is redundant (*horse* appears in both propositions). The question is whether the shared element – the horse – appears once or twice in the underlying predicate frame of the conjoined sentence. If *horse* appears twice – [(*horse* climbs house) & (*horse* sleeps)] – the sentence will have an underlying frame of 5 units. If *horse* appears once – *horse* [(climbs house) & (sleeps)] – the sentence will have an underlying frame of 4 units. In fact, it turns out that production probability decreases systematically with increases in underlying predicate frame *only if* we take shared elements into account when calculating the size of a predicate frame – in particular, only if we assign shared elements one slot (rather than two) in the underlying frame (Goldin-Meadow 1982).[6]

I am not arguing that the deaf children fail to attribute two roles to the climbing and sleeping horse at some, perhaps semantic or propositional, level. There is no reason to think they don't. However, the children's production probability patterns make it clear that we need a level between this semantic/propositional level and the surface level of the sentence – a level in which dual-role elements appear only once. This underlying level is necessary to account for the surface properties of the deaf children's sentences.

The point I want to stress here, however, is that in order to account for the production probability patterns we find in the deaf children's multi-proposition

6. There are many aspects of sentence construction that we do not yet understand in the deaf children's homesigns. For example, we cannot predict the number of signs a child will produce in a given sentence; that is, we cannot explain why the child produces three rather than four signs in the *climb–sleep–horse* sentence. All we can do is state with some assurance that if the child were to produce another sign, that sign is likely to indicate the house, the patient in the first proposition (as opposed to, say, a sign indicating the location where the activity takes place). Note also that the shared actor, *horse*, occurs at the end of the sentence, after the verb *sleep*. Typically, intransitive actors occur before the verb. The fact that the actor is shared across the two propositions may account for its placement in an atypical post-verb position; however, we need many more sentences of this type before we can determine whether this placement for shared actors is a consistent pattern in the child's homesigns.

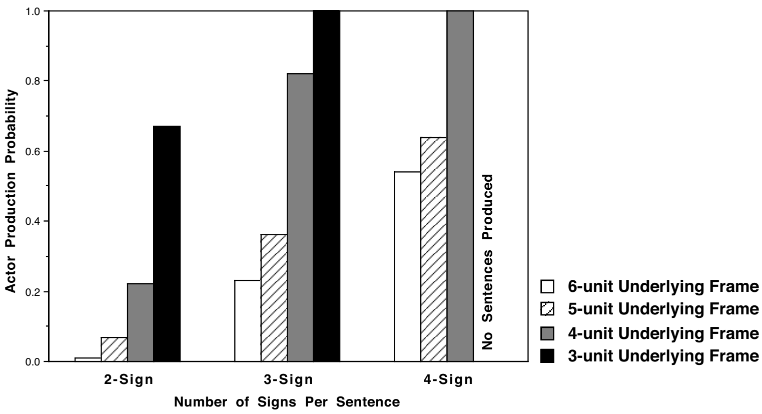

Figure 3. The production of signs for semantic elements in complex sentences depends on the conjoined predicate frames underlying that sentence. The figure displays the likelihood that a deaf child will produce a sign for an actor in 2-, 3-, and 4-sign complex sentences as a function of the conjoined predicate frames underlying that sentence. Like the production probability patterns seen in the simple sentences displayed in Figure 1, actors are more likely to be produced in sentences with smaller underlying frames, presumably because there is less "competition" for the limited number of slots in surface structure in these sentences. Not surprisingly, production probability goes up overall as the number of signs in the sentences increases – but the pattern in relation to the underlying frame remains the same.

sentences, we need to consider overlaps (i.e., redundancies) across the propositions. In other words, because the underlying frame must take into account whether a semantic element is shared across the propositions contributing to that frame, it cannot reflect mere *juxtaposition* of two predicate frames – we need to invoke an overarching organization that encompasses all of the propositions in the sentence to account for the child's production probability patterns. Thus, the deaf children's complex sentences result from the unification of two propositions under a higher node and, in this sense, display hierarchical organization.

3.6. Vocabulary for relational concepts

We have seen that the deaf children can exploit a variety of devices (linear order, production probability, inflection) to indicate semantic relations. Another device that Jackendoff highlights is the invention of words expressing a semantic relation, and he lists a number of different types of "utility" vocabulary items that modern languages have. Although we have not found evidence for all of these types, the deaf children do invent signs for some of the terms on Jackendoff's list.

The children invent signs that refer to displacement in time and space (Morford and Goldin-Meadow 1997). For example, one of the deaf children produced a sign, never observed in his hearing parents, to refer to remote future and past events – needing to repair a toy (future) and having visited Santa (past). The sign is made by holding the hand vertically near the chest, palm out, and making an arcing motion away from the body. This sign, which we gloss as *away*, was always used to refer to events that were displaced both spatially and temporally. Another child invented a comparable sign to refer only to past events.

In addition to these two novel signs, the deaf children modified a conventional sign that is typically used to request a brief delay or time-out. This sign, which we gloss as *wait*, is formed by holding up the index finger. In addition to using the sign for its conventional meaning, the deaf children used it to identify their intentions, that is, to signal the immediate future. For example, one child signed *wait* and then pointed at the toybag to indicate that he was going to go retrieve a new toy. The children's hearing parents used the *wait* sign to get their children's attention, never to refer to the immediate future. The form of the sign was very probably borrowed from the children's hearing parents, but the meaning was their own (although it is a reasonable extension of their parents' meaning for this sign).

The children modified a second conventional sign typically used to express doubt or uncertainty. The sign is made by holding both hands out to the sides, and then flipping the hands from palm down to palm up; the hand movements are often accompanied by a shrug of the shoulders. In addition to using the sign for its conventional meaning, the children also used it to signal non-visible objects. When used in this context, the sign conveys the meaning *where*. For example, one child was looking at flashcards and saw a picture of a fish. Later, when looking at a book, she saw another picture of a fish which prompted her to combine a point to the picture in the book with the *where* sign to request that the experimenter help her find the original flashcard with the fish. The children's hearing parents used the *where* sign only to express doubt and uncertainty, never to request non-visible objects.

The children also used particular signs as markers of illocutionary force and modality. For example, they produce the *where* sign to mark questions, a *mouth-open* sign to mark exclamations, a brief *nod* to mark imperatives, and a *side-to-side headshake* to mark negative constructions. Headshakes are also used as a more general discourse connector. For example, one of the deaf children and I were playing a game rolling toys to each other's legs. The child signed *pear-banana+[headshake]-roll* to tell me that he thought the pear would roll toward his leg *but* the banana would not. We have not yet examined the data to determine how systematic these uses are, but it is clear that the children invent some signs, and borrow others, to convey relational concepts. There is thus evidence that they have taken this step toward modern language.

3.7. Grammatical categories and morphology

According to Jackendoff, phrase structure and the utility vocabulary still do not constitute a modern language. Many properties are lacking: a notion of subject and object (as opposed to semantically defined notions like agent and patient), grammatical differentiation of parts of speech (as opposed to object and action words), inflection for case and agreement, pronouns and other proforms, a regimented way of constructing long-distance dependencies. We have not yet searched for all of these properties in the deaf children's signs, but we do have evidence for grammatical categories and inflections (and perhaps proforms) from our analyses of one deaf child.

The child we have studied has invented morphological and syntactic devices to distinguish nouns and verbs. For example, if the child uses *twist* as a verb, that sign would likely be produced near the jar to be twisted open (i.e., it would be inflected, see Section 3.4.3), it would not be abbreviated (it would be produced with several twists rather than one), and it would be produced *after* a pointing sign at the jar (*that–twist*). In contrast, if the child uses that same form *twist* as a noun to mean "jar", the sign would likely be produced in neutral position near the chest (i.e., it would not be inflected), it would be abbreviated (produced with one twist rather than several), and it would occur *before* the pointing sign at the jar (*jar–that*). Thus, the child distinguishes nouns from verbs morphologically (nouns are abbreviated, verbs inflected) and syntactically (nouns occur in initial position of a two-sign sentence, verbs in second position). Interestingly, adjectives sit somewhere in between, as they often do in natural languages – they are marked like nouns morphologically (*broken* is abbreviated but not inflected) and like verbs syntactically (*broken* is produced in the second position of a two-sign sentence).

But what evidence do we have that these categories are nouns and verbs, as opposed to names for objects and actions? To pursue this question, we recoded a subset of the child's signs using contextual criteria developed by Huttenlocher and Smiley (1987) to determine when a lexical item refers to an object vs. an action. We then determined whether the deaf child's noun-verb categories could be reduced to object-action categories. We found that they could not, particularly after age 3;3. Before age 3;3, coding the child's signs in terms of nouns and verbs resulted in precisely the same distributions as coding them in terms of objects and actions. However, after age 3;3, the two sets of categories were distinguishable and, where the two sets of codes diverged, the morphological and syntactic devices described above patterned according to the noun-verb codes rather than object-action codes (Goldin-Meadow et al. 1994: 300–301).[7] In other words, prior to age 3;3, the deaf child's categories could have been either grammatical (noun-verb) or semantic (object-action), but after 3;3, there was good evidence that they were grammatical.

Of course, we can never prove beyond a doubt that the categories we isolate are the grammatical categories of noun and verb. Nevertheless, the categories do resemble nouns and verbs in natural languages in three respects, lending weight to the claim that the categories are grammatical. First, there is coherence between the morphological and syntactic devices in the child's system. Inflections mark verbs, abbreviations mark nouns; virtually *no* signs are produced with both markings. And, nouns and verbs occupy different positions in sign sentences. Second, adjectives in the deaf child's system behave like nouns morphologically but like verbs syntactically, as do adjectives in some natural languages (Thompson 1988). Finally, in the few instances in the deaf child's system where a verb combines with an iconic noun sign (as opposed to a pointing noun sign), the noun sign adheres to the syntactic rules of the system. For example, the child placed an iconic noun sign playing a patient role (*grape*) before the verb (*give*), just as he routinely places pointing signs playing a patient role before the verb. In other words, when iconic noun signs are produced in sentences with verbs, they are treated in precisely the same way as pointing pronoun signs. Thus, the grammatical categories noun and verb are elements within the deaf child's syntactic system and, as such, are governed by the rules of that system, just as nouns and verbs are governed by the rules of syntax in natural language.

3.8. What's function got to do with it?

Jackendoff does not stress the functions to which language is put and perhaps he is correct to ignore them. However, it is worth noting that the deaf children use their signs for a wide variety of functions (Goldin-Meadow 2003a) – to comment not only on the here-and-now but also on the distant past, the future,

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7. Prior to age 3;3, all of the signs coded as verbs occurred in contexts where the relevant object and action were both present, and all of the signs coded as nouns occurred in contexts where object and action were both absent. After 3;3, both noun and verb signs were found not only in these clear contexts but also in ambiguous contexts – where the object was present but the action was not. In these instances, the morphological and syntactic patterns continued to follow the noun-verb codes, despite the fact that the context was not clearly associated with either objects or actions; in other words, the form of the signs could be predicted on the basis of the grammatical noun-verb codes rather than the semantic object-action codes.

and the hypothetical; to make generic statements so that they can converse about classes of objects; to tell stories; to talk to themselves; to talk about their own and others' signs. In other words, they use their signs for the functions to which all natural languages are put.

Thus, not only do the deaf children structure their signs according to the patterns of natural languages, but they also use those signs for the functions natural languages serve. Structure and function appear to go hand-in-hand in the deaf children's sign systems. But the relation between the two is far from clear. The functions to which the deaf children put their signs could provide the impetus for building a language-like structure. Conversely, the structures that the deaf children develop in their signs could provide the means by which more sophisticated language-like functions can be fulfilled. More than likely, structure and function complement one another, with small developments in one domain furthering additional developments in the other. In this regard, it is interesting to note that language-trained chimpanzees are less accomplished than the deaf children in terms of *both* structure and function. Not only do the chimps fail to display most of the structural properties found in the deaf children's sign systems, but they also use whatever language they do develop for essentially one function – to get people to give them objects and perform actions (see, for example, Greenfield and Savage-Rumbaugh 1991).

4. What homesign does not have and why

The structural and functional properties found thus far in the deaf children's homesign systems are summarized in Table 1. Although there is no guarantee that these findings bear on the problem of language acquisition in children who are exposed to conventional language, the more the properties in Table 1 resemble those found in natural languages, the more confident we can be that homesign is relevant to language-learning and Universal Grammar. It is difficult to point to a single list of properties that everyone agrees constitutes Universal Grammar. Nevertheless, it is not unreasonable to suggest that the properties found in the deaf children's homesign systems ought to be part of anyone's characterization of Universal Grammar. But what about the properties of Universal Grammar *not* found in the deaf children's homesigns? The findings in Table 1 make it clear that the deaf children have taken several steps beyond what Jackendoff calls "unregulated concatenation" in their sign systems. However, the children have not invented anything like a full syntax,[8] and

8. The deaf children are also not likely to have invented a full phonology, but we have not yet explored this particular domain in homesign.

they undoubtedly lack some properties that have been attributed to Universal Grammar on theoretical grounds.[9]

But should we expect homesign to exhibit all of the properties of Universal Grammar? As far as I know, no one argues that Universal Grammar operates in a vacuum. Certain aspects of the language-learning situation are very likely to be essential for Universal Grammar to manifest itself in a child's communication. The challenge is to figure out what those environmental conditions are. We know that a conventional language model is *not* necessary for the properties listed in Table 1 to flourish. A conventional language may well be essential for properties not found in Table 1 to develop, but there are at least two other conditions (besides the absence of linguistic input) that could explain the deaf children's inability to develop all aspects of Universal Grammar. First, the deaf children lack a communication partner who is willing to enter into their sign system with them. The children's hearing parents interact with them and talk to them all the time, but they are not "speakers" of their children's language. The gestures that the hearing parents produce are no different from the gestures that other hearing speakers produce when they talk, and thus are structured quite differently from the deaf children's homesigns (Goldin-Meadow 2003b). The second factor that may be holding the deaf children's sign system back is that it is only one generation deep. In order for a language to reach the next "step," it may have to be seen with fresh eyes.

Findings from the newly emerging Nicaraguan Sign Language suggest that both factors may be important in language growth. The initial step took place when deaf children in Managua were brought together for the first time in an educational setting (Kegl et al. 1999). The deaf children had been born to hearing parents and, like the deaf children described here, were likely to have invented sign systems in their individual homes. When they were brought together, they needed to develop a common sign language – and they did. But Nicaraguan Sign Language has not stopped there. Every year, new students enter the school and learn to sign among their peers. This second cohort of signers has as its input the sign system developed by the first cohort and, interestingly, changes that input so that the product becomes more language-like (Senghas and Coppola 2001). For example, the second cohort signers go beyond the small set of basic word orders used by the first cohort, introducing new orders not seen previously in the language (Senghas et al. 1997). Moreover, the second cohort continues to use spatial devices invented by the first cohort but uses these devices consistently and for contrastive purposes (Senghas and Coppola 2001). The second cohort, in a sense, stands on the shoulders

9. It is, of course, possible that properties missing from Table 1 really are part of homesign but that we have not yet looked in the right place to find them – we could, for example, look at adult homesigners who have had more time to generate their systems.

Table 1. The resilient properties of language

The resilient property	As instantiated in the deaf children's homesign systems
Words	
Stability	Sign forms are stable and do not change capriciously with changing situations
Paradigms	Signs consist of smaller parts that can be recombined to produce new signs with different meanings
Categories	The parts of signs are composed of a limited set of forms, each associated with a particular meaning
Arbitrariness	Pairings between sign forms and meanings can have arbitrary aspects, albeit within an iconic framework
Grammatical functions	Signs are differentiated by the noun, verb, and adjective grammatical functions they serve
Words for relational concepts	Particular signs are used to signal past, future, uncertainty and to mark illocutionary force
Sentences	
Underlying frames	Predicate frames underlie sign sentences
Deletion	Consistent production and deletion of signs within a sentence mark particular thematic roles
Word order	Consistent orderings of signs within a sentence mark particular thematic roles
Inflections	Consistent inflections on signs mark particular thematic roles
Recursion	Complex sign sentences are created by recursion
Redundancy reduction	Redundancy is systematically reduced in the surface of complex sign sentences
Language use	
Here-and-now talk	Signs are used to make requests, comments, and queries about the present
Displaced talk	Signs are used to communicate about the past, future, and hypothetical
Generics	Signs are used to make generic statements, particularly about animals
Narrative	Signs are used to tell stories about self and others
Self-talk	Signs are used to communicate with oneself
Metalanguage	Signs are used to refer to one's own and others' signs

of the first. Comparing homesigners, alone and in groups, and over generations can help us identify those environments that permit humans to develop language systems characterized by Universal Grammar and those environments that do not.

5. Resilient properties of language and Universal Grammar

5.1. Language is not all-or-none

Jackendoff suggests that we should view Universal Grammar as a toolkit – languages pick and choose which of the tools they use. Under this view, grammar is not a single unified system but a collection of simpler systems. This way of viewing language is reminiscent of the picture of language that I have come to after studying sign systems invented by children without benefit of linguistic input. I have proposed that certain properties of language are *resilient*, operationally defined as those properties that children can develop without access to a conventional language model (Goldin-Meadow 1982, 2003a; see Table 1). Other properties that cannot be developed under these conditions are considered *fragile.* For example, the deaf children have not developed a system for marking tense. Importantly, properties that have been identified as resilient on the basis of the deaf children's homesigns turn out to be resilient in the face of other variations in language-learning circumstances (e.g., learning language beyond the critical period, Goldin-Meadow 1978). The interesting empirical question is whether properties that are found in most of the languages in the world – that is, the most popular tools in the Universal Grammar kit – are also the resilient properties of language.

Data from the deaf children can also inform our views of Universal Grammar in terms of defaults. For example, Hyams (1986) has hypothesized that all children start out with a grammar that licenses null subjects. However, she has become convinced that the child's initial state prior to experience may have to be determined logically, rather than empirically, simply because linguistic input begins to alter the child's initial state almost immediately (Hyams 1994: 297–298). I suggest that the deaf children's sign systems can provide *empirical* data on the child's initial grammatical state – and the data support Hyams' view that children come to the language-learning situation with the expectation that subjects (transitive actors in the deaf children's sign systems) can be omitted. Children seem to need a language model to override their default assumption that subjects ought not be expressed.

In some domains, children may come to language-learning without a bias or default setting, and data from the deaf children can provide useful data here as well. Children discover relatively early that they are learning either a right-branching (English) or a left-branching (Japanese) language (Lust 1981). Discovering the branching direction of the language they are learning has ramifications throughout the children's linguistic system. Do children have a bias toward right- vs. left-branching systems before being exposed to linguistic input? No – at least not according to the data on the deaf children's complex sign sentences (see Goldin-Meadow 1987). The deaf children show no bias of any sort, suggesting that the initial grammatical state may be neutral on this dimension.

5.2. Is language innate?

The fact that all known human groups (even those incapable of hearing) have developed language is reason enough to consider the possibility that language-learning is innate. And the fact that human children can invent components of language even when not exposed to any linguistic input makes it more likely still that language-learning ought to be considered innate. However, the problem in even beginning to address this issue is finding a comfortable definition of "innate."

One might naively think that if learning is involved in the development of a behavior, the behavior cannot be innate. However, we'd like our definition of innate to be more subtle – some learning is involved in the acquisition of all human skills, even one as basic as walking (Thelen and Ulrich 1991). The issue is not whether learning has occurred but whether learning is guided by the organism as much as, if not more than, by the environment. Another way of talking about the organism's role in the learning process is that the range of possible outcomes in the process is narrowed, and the organism itself does the narrowing. This narrowing, or "canalization," is often attributed to genetic causes (cf., Waddington 1957). However, canalization can also be caused by the environment. For example, exposing a bird to a particular stimulus at one point early in its development can narrow the bird's learning later on – the bird becomes particularly susceptible to that stimulus, and buffered against responding to other stimuli, at later points in development (Gottlieb 1991). Thus, for any given behavior, we need to investigate the causes of canalization rather than assume a genetic base.

In the deaf children's case, we know that the structures found in homesign cannot have been shaped by a conventional language model simply because the children have none. Moreover, the homesign structures cannot be traced to the co-speech gestures that the deaf children's hearing mothers produce. The hearing mothers' gestures cannot easily be characterized as having either sentential (Goldin-Meadow and Mylander 1998) or morphological (Goldin-Meadow et al. 1995) structure, and the little structure that a mother's gestures do exhibit differs from the structure found in her deaf child's homesigns. It is very possible, however, that the deaf children's non-linguistic experiences are providing candidate structures (i.e., canalizing experiences) for their homesign systems. But note that not every cognitive structure that a child develops is going to end up in homesign. Even if all of the structures found in homesign can be traced to other non-language domains (i.e., even if none of the structures in homesign is specific to homesign), we still need to explain why this particular subset of structures was co-opted for language.

In human studies, we cannot freely engineer organisms and environments, and developmental histories are quite complex. It is therefore difficult to attribute canalization to either genetic or environmental causes. Does this difficulty render the notion "innate" meaningless? Not necessarily. The definition of "innate" need not be anchored in genetic mechanisms. Indeed, of the large number of criteria that have, over many years and many disciplines, been applied to the term "innate," Wimsatt (1986) argues that the one that is *least* central to the notion's core is having a genetic base (see also Block 1979; Spelke and Newport 1998). In his view, a more fundamental definition is *developmental resilience*. A behavior that is developmentally resilient is one whose development is, if not inevitable, certainly one that each organism in the species is predisposed to develop under widely varying circumstances. Language seems to be a prime example of such a behavior.

Indeed, I suggest that it is someone else's job to figure out what the genetic basis for language-learning is simply because, unless we know the genetic profiles of the language users we are studying, no linguistic analysis can ever tell us whether a particular gene controls the development of a particular linguistic property – it's the wrong level of analysis. As linguists and psychologists, we can make important contributions to the quest for the biological underpinnings of language-learning by isolating properties that are universally shared across languages and cataloging which of these properties is robust enough to be developed in atypical learning environments. Findings of this sort can then guide geneticists to the places where it may be fruitful to seek an explanation at the biological level. I stress, however, that my goal in describing homesign is to identify the core properties of human language. In this regard, it is important to note that a linguistic property is no less central to human language if its development turns out to be guaranteed, not by a particular gene, but by a combination of genetic, hormonal, neurological, and environmental factors.

I therefore suggest that innateness is most usefully evaluated through the perspective of developmental resilience. Innateness can be operationalized by specifying the range of environments in which particular aspects of language-learning develop. There clearly are limits on language development in humans – children raised without humans do not develop language. But language development can proceed even in the face of radical deviations from typical learning environments, in the case I have described here, in the absence of a conventional language model. By exploring language's resilience to such extreme environmental variation, we learn that certain aspects of language are central to humans – so central that their development is virtually guaranteed. It is these aspects of language that ought to be part of anyone's account of Universal Grammar, and indeed they are part of Jackendoff's. Thus, homesign and other manipulations probing the resilience of language can serve not only as an empirical test of linguistic theory but also as a source of hypotheses for linguistic theory, in particular, as a source of candidate properties for Universal Grammar.

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