How Language Learns:
Linking Universals to Acquisition

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A recurring question in the study of human language is the origin of its complex structure. Languages are systems of abstract, hierarchically organized symbolic information, capable of generating an infinite number of expressions. Even so, every individual person masters a complete language, without explicit study, in the first few years of life.

Complex natural systems do not arise fully formed; they evolve from simpler systems. What are the origins of linguistic structures, and what processes might have promoted an increase in complexity over time? The structures of languages are constantly changing, as they are passed from one generation to the next, and remnants of earlier variants remain in modern forms. We can consider this process to be one of evolution, with some traits of a language being "selected" and successfully passed down, while other traits are repurposed or disappear altogether.

If we are to adopt this evolutionary view of language in more than a metaphorical sense, we must consider seriously the mechanisms of reproduction. In the case of languages, reproduction occurs when a language is learned; a language reproduces once in the lifetime of each individual learner. Children observe language being used, adopt a structure similar to that of the observed language, and reproduce the language in their own communication. Accordingly, no piece of language, no matter how useful or elegant, will survive if children are not inclined to acquire it. A change in a language suggests that, for learners, the deviation from the past variant may have been more easily acquired, or more naturally inferred, based on the language model that they observed. In other words, explanations for diachronic facts lie in acquisition.

We must appeal to acquisition to explain not only how a language changes, but also how it retains its aspects over generations. Individual speakers from one generation cannot pass a grammar, whole cloth, to their children. All they can do is display their language, and allow children to apply their learning mechanisms to this input to weave a similar structure of their own. How do children convert a stream of language percept into an internal, highly structured abstract system?

Utterances occur in a communication context. As each sentence is presented, the child must surmise its meaning, linking it to some event in the world. However, this mapping does not occur directly between parts of the

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utterance and aspects of the world. There are infinitely many facets of an event, and not all of them will be linguistically represented. Furthermore, a single event can be described from different perspectives, yielding different meanings to the words that describe it. For example, *a tiger chasing a boy* and *a boy fleeing a tiger* could refer to the same event, but the words *chase* and *flee* have quite different meanings. Each refers to a different construal of the same event. Even very young children are not confused by this distinction, and are highly sensitive to the linguistic cues that indicate the intended perspective (Fisher, Hall, Rakowitz, & Gleitman, 1994; Fisher, 1994).

Sentences do not map onto events; they map onto construals of events. As children interpret a sentence, they seek to align recognized components of the sentence with components of the construal. For an event construed as *chasing*, they will identify a chaser, an action, and a chas-ee. If their understanding is incomplete, and they cannot successfully align the utterance with a construal, I suggest that they will need to make adjustments to either their analysis of the utterance, or the construal. They will need to divide and recombine parts of their existing representation to achieve correspondence between form and meaning.

Dividing and combining are complementary processes that together enable the hierarchical structures of a language to be discovered and rebuilt. Like gestalt principles, they guide the language learner to find linguistic objects, and their relationships, within the utterance stream. Combining brings elements together to form a single structural unit. This process can be repeated, resulting in nested structures. However, a learner cannot combine elements before learning the combinatorial patterns in the language. This is where dividing comes in – dividing breaks down a single larger component into multiple smaller components. This enables the learner to isolate the basic elements in a language, and also discover the patterns for recombination.

This dividing and combining happens at every level of language, right down to identifying individual elements within a stream of percept. Imagine, for a moment, the repeated two-tone sound of an ambulance siren, or the clip-clop of a trotting horse. If alternating elements contrast in intensity, we mentally divide the stream into pairs of trochees, with the strong element first. In contrast, if alternating elements differ in duration, we mentally divide the stream into pairs of iambs, with the long element second. These iambic and trochaic principles were first noted in music (Bolton, 1894), but have more recently been studied in language (e.g., Morgan, 1996; Nespor et al., 2008; Hay & Saffran, 2012). For a child parsing a stream of language, patterns that correspond to initial biases would be more easily learned, and units detected or constructed through these processes could later be identified in other combinations, leading to the learning of regularities within the specific language, such as the order of sounds within words, and words within phrases.

As a language is passed down, it is subject to these combining, dividing, and re-aligning mechanisms in every new learner. This process of reproduction is not exact, and each instance of learning is an opportunity for a language to change. Naturally, combinations that are difficult to break down, or mappings

that are unintuitive, are likely to change or disappear. Furthermore, because aspects of a language are advantageous to the extent that they are shared within a linguistic community, any shared intuitions will be favored. Even slight biases in the ease of learning certain patterns or word-meaning mappings could have a significant impact on a language over multiple iterations of learning, as long as those biases were shared (Kirby, Dowman, & Griffiths, 2007).

We can view a language as a system that adapts to its learners as it is is imperfectly and repeatedly recreated over generations (Deacon, 1997; Keller, 1995). The nature of the changes in a language over time should reveal common predispositions of its learners, from the patterns of sounds that make up words, to the patterns of meaning components that make up event construals. In the typical case, where a language has been passed down through many generations of similar learners, the language has been shaped so as to be highly learnable (Christiansen & Chater, 2008); consequently, the input highly resembles the output, and the influence of any one learner is immeasurable. We cannot know, by looking at the structure of a modern spoken language, whether any given feature is the inevitable outcome of language learning mechanisms, or merely compatible with them, having evolved over millennia.

Changes in an emerging sign language

Research documenting newly emerging languages allows us to see the shaping effects of acquisition mechanisms more prominently. In Nicaragua, a sign language has arisen recently enough that its first stages can be observed; indeed, its originators are still living. An advantage offered by an early sign language is that the input to the system is natural gestural communicative behavior, but is not a rich language shaped by generations of learning. The measurable differences between the input to learners and the language that they ultimately produce reflect the nature of language acquisition mechanisms.

Since the mid-1970s in Managua, rapidly expanding day-school programs in special education brought deaf children and adolescents together in numbers greater than before. Although teachers emphasized learning to speak and lip-read Spanish, an initial group of 50 students spontaneously began communicating among their peer group using gestures. The system of signing they developed was taken up by new children entering the school, every year since it opened its doors. Today Nicaraguan Sign Language (NSL) is a rich, developed sign language that serves as the primary daily language of approximately 1500 deaf people, ranging from four years of age to the mid-50s. In order to capture the changes in the language as it developed, we systematically compare groups of signers based on the year that they entered the new community and learned the language. What I refer to as the first cohort of signers entered within the first decade, before the mid-1980s, by which time NSL had been learned by about 400 individuals. A second cohort acquired NSL in its second decade, by which time about 600 individuals had learned it. A third cohort acquired NSL in its third decade, by which time about 800 individuals had learned it. Differences

between these age cohorts today reflect changes to the language as it was learned.

One line of evidence has focused on changes in expressions of motion events, from holistic to segmented signing. Consider an event in which someone rolls down a hill. This event includes a manner of movement and a path of movement that occur inseparably in the world – one cannot engage in rolling without simultaneously moving along some path. And yet, languages around the world construe such motion events as a combination of manner and path components, representing these two aspects of the events with separate elements in the sentence (Talmy, 1985). How is this information bundled in descriptions of motion in an emergent language? We found that hearing Nicaraguans who are gesturing naturally while speaking will produce gestures in which the manner and path are inseparable, just like in the world: The hand simultaneously makes a bouncing or circular movement while moving downward (Fig. 1).

Figure 1. Manner and path expressed simultaneously. In this example a hearing Spanish-speaker describes a character rolling down a hill with a bowling ball in his belly; the gesture shown naturally accompanies his speech. Here manner (wiggling) and path (trajectory to the speaker's right) are expressed together in a single holistic movement (from Senghas, Kita, & Özyürek, 2004).

Such a gesture is an iconic analog of the event. It has no internal structure beyond the internal structure of the event in the world. Since rolling and descending happen simultaneously in the world, they appear simultaneously in the gesture. The mapping is holistic; the entire gesture represents the entire event.

These are the kinds of gestures that signers from the first cohort must have seen being used around them every day, as they were first creating NSL. In their own signs, we observed a similar iconic, holistic movement that referred to the entire motion event (Senghas et al., 2004). Additionally, about half of their expressions included, along with the holistic sign, a simpler manner-only or path-only sign (Fig. 2) (Senghas et al., 2013).

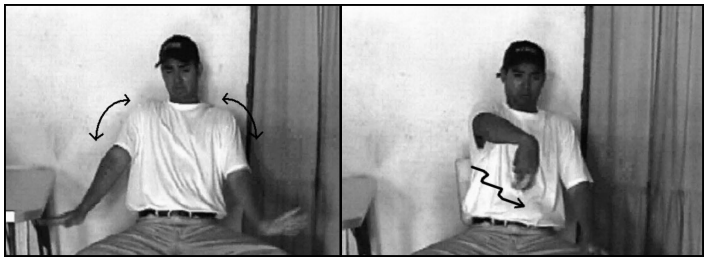

Figure 2. A first-cohort NSL signer describes a character rolling down a hill with a bowling ball in his belly. He first produces a body gesture for the side-to-side waddling manner, followed by a gesture conflating both the waddling manner and the forward path (From Senghas, Özyürek, & Goldin-Meadow, 2013).

In these expressions, one aspect of the motion event, such as the rolling manner, has been separated from the event. It corresponds to its own element in the utterance, in this case, a ROLL sign. However, the expression of the relationship between the manner and path of movement still reflects their relationship in the world; manner and path are expressed simultaneously in a single, holistic ROLLING-DOWN sign.

As we turned to the signing of the second and third cohort, we found that motion event expressions had been transformed into fully segmented sequences of manner-only and path-only signs (Fig. 3).

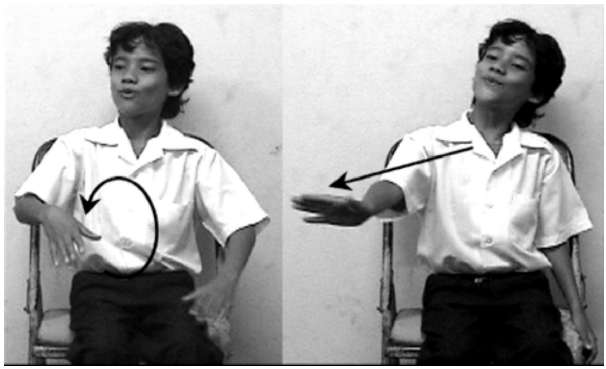

Figure 3. Manner and path expressed sequentially. A third-cohort signer describes a rolling event in NSL. Here manner (circling) and path (trajectory to the signer's right) are expressed in two separate signs, assembled into a sequence (from Senghas, Kita, & Özyürek, 2004).

In this newest form of motion event expressions, some of the analog, iconic structure of the utterance has been sacrificed, since the rolling and descending occur inseparably in the world, but separately in the utterance. The holistic ROLLING-DOWN sign has been reanalyzed, and divided into two more elemental signs: one a circular movement, the other a downward trajectory. The motion event has been correspondingly divided into a manner of motion and a path of motion. And finally, a realignment and re-mapping linked the new signs to the new meanings, completing the production of new signs for ROLL and DESCEND. The two new signs could now be combined in a string to describe an event in which a character rolls down a hill. As it stands alone, the new utterance might seem less efficient, since two signs are needed to express something previously described with one sign. However, the overall system enables signers to generate expressions describing more kinds of motion events with a smaller set of lexical items, since basic manners of movement (e.g., rolling, climbing, running) can now be combined with basic paths (e.g., upward, downward, zigzag).

Over a few generations of learning, Nicaraguan signers produced a language that was quite different from their input. They reanalyzed expressions in which manner and path were produced simultaneously, turning them into sequences of simple manner and path units. One might ask whether this process of segmentation, repeated over many generations, would eventually transform all language into multi-segment, sequenced strings of signs. Perhaps learners have a bias against the simultaneous production of manner and path of motion. To address this question, we examined motion event expressions produced by signers of a mature sign language from Spain, Lengua de Señas Española (LSE). Presumably when it originated centuries ago, LSE, like NSL, drew from holistic gestures used by hearing people around them to describe motion events. When we elicited motion event descriptions from native signers of LSE living in Madrid and Seville, we discovered that, unlike the recent Nicaraguan signers, LSE signers do not prefer segmented expressions, and are most likely to produce manner and path simultaneously in a single complex sign (Senghas & Littman, 2004).

If non-signers' gestures, NSL, and LSE can be taken to represent stages of language emergence, the pattern of results initially suggests a U-shaped trajectory of development, from simultaneous to sequential to simultaneous. However, a closer look reveals combinatorial processes behind the LSE signs. Sign languages are subject to pressures that favor simultaneous combinations of elements, taking advantage of the signing space and multiple articulators, including the hands, torso, and head. Such combinations were evident in many of the LSE signs, as in a rolling manner expressed with one articulator and downward path with another, produced simultaneously. In other expressions, manner and path were combined into a single, complex movement, indistinguishable from a holistic gesture (Fig. 4) (Coppola & Senghas, 2017).

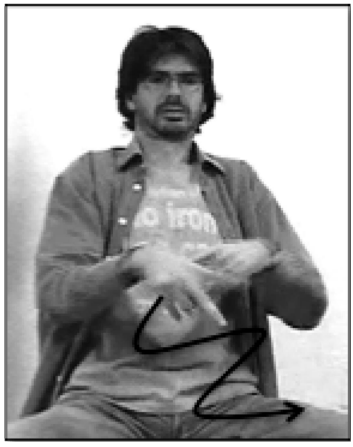

Figure 4. Manner and path expressed simultaneously. An LSE signer describes a character rolling down a hill with a bowling ball in his belly. Here manner (wiggling) and path (trajectory forward and downward) are expressed together in a single movement (from Coppola & Senghas, 2017).

One cannot know, examining a single utterance, whether it is a holistic representation, or has internal combinatorial structure. Only by identifying the same units within different utterances can one discover the combinatorial patterns. It appears that child learners treat their language input, whatever its source, as if it had been created by a combinatorial linguistic system. Consequently, children learning a mature language like LSE today do not convert it into a grammar that produces only sequential, segmented signs, because the language has systematic, internal combinatorial structure that is discoverable by child learners.

This cross-linguistic analysis suggests that the path from gestures to sign language begins with holistic expressions, which become partially segmented, then fully segmented, and then finally recombined to build complex expressions. The output language of each generation does not faithfully reproduce the input, nor does it fall back on a common default. The process is one of progressive realignment between motion events in the world, construals of those events, and utterances that map, part for part, to those construals. These changes come about through dividing and combining processes available to every learner. Because each successive wave of learners is operating on different input, the outcome is different at every stage. Through this process, even nonlinguistic communicative expressions can serve as the raw materials to build a language. Ultimately, after several iterations of learning, they will be reshaped into a complex combinatorial system that can be acquired easily by any child.

Evidence from typical acquisition of mature sign languages suggests similar processes in action. Children may discover basic units in their language by pulling apart complex constructions at the joints. Morphemes that are typically

bound can consequently appear in isolation in child signing. For example, in American Sign Language (ASL), complex verbs simultaneously include subject and object information through spatial modulations. In research on the acquisition of ASL verb agreement, Meier (1987) found that children initially produce sequential strings of morphemes rather than combine verb agreement elements into the single, complex movement found in their adult models. Over-segmentation during the acquisition of ASL has been observed across a number of element types, including the agent and patient of a transitive event, and, as in NSL, the manner and path of a motion event (Newport 1981; 1990). Of course, as young learners continue to be exposed to the complex expressions produced by fluent signers of ASL, they discover its combinatorial structure and converge on the target grammar, leaving their over-segmenting habits behind.

Evidence of age effects

A striking pattern in the community of signers of Nicaraguan Sign Language is that a record of the changes from one generation to the next are preserved, in order, even in the present-day systems of the adults. Recall that as we compare deaf Nicaraguan fifty year olds, to forty year olds, to thirty year olds, we find the most developed form of NSL in the younger adults, not in the older adults who have more years of experience with the language. Of course, cultural transmission requires adjacent age cohorts to be in social contact with each other, and the conversations go both ways, but the transmission and change is unidirectional.

This pattern reveals that children and adults have different effects on the language. If adults using NSL were able to shape it as children do, or were as able to learn the changes that others developed, we would find no differences today between adult age cohorts. Everyone would learn the same, most up-to-date variant through their shared contact, at every age. The fact that older signers retain an earlier form suggests that they stopped adapting and realigning their language system, while the next-younger cohort that followed them continued to change.

Children's approach to language acquisition is more than a general impulse to analyze and recombine; children develop intuitions about precisely how to carry out the realignment as they learn the language. The ecology of the language, as it develops in the child, will influence the patterns the child can later discover. Regularities in one domain can bleed over into another domain, having cascading effects. Returning to our example about trochaic and iambic biases, it appears that the trochaic bias emerges spontaneously, independent of experience, while the iambic bias must be learned from exposure. This bias of grouping could be used to reveal syntactic properties, such as whether a language is head-initial or head-final (Toro 2016). The challenge in language acquisition is discovering such specifics. Which aspects of languages are the inevitable outcomes of acquisition mechanisms, and what are the (merely) compatible features that emerged slowly over millennia of cultural evolution?

What is it that can be encoded in language, and what kinds of mappings motivate children's analyses? Do all languages construe motion events as a combination of a manner and a path? Do all languages construe action events as entailing agents? The study of emerging languages, in conjunction with typical acquisition and historical language change, can help us pinpoint which kinds of changes represent a random walk from the input, and which have children as their guide.

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