Bahrick LE and Lickliter R (2002) Intersensory redundancy guides early perceptual and cognitive development. In: Kail R (ed.) *Advances in Child Development and Behavior*, vol. 30, pp. 153–187. New York: Academic Press.
Bahrick LE and Watson JS (1985) Detection of intermodal proprioceptive visual contingency as a potential basis of self-perception in infancy. *Developmental Psychology* 21: 963–973.
Bahrick LE, Walker AS, and Neisser U (1981) Selective looking by infants. *Cognitive Psychology* 13: 377–390.
Gibson EJ and Pick AD (2000) *An Ecological Approach to Perceptual Learning and Development*. New York: Oxford University Press.
Gogate L, Walker-Andrews A, and Bahrick LE (2001) Intersensory origins of word comprehension: An ecological-dynamic systems view. *Developmental Science* 4: 1–37.
Lewkowicz DJ (2000) The development of intersensory temporal perception: An epigenetic systems/limitations view. *Psychological Bulletin* 126: 281–308.
Lewkowicz DJ and Lickliter R (1994) *The Development of Intersensory Perception: Comparative Perspectives*. Hillsdale, NJ: Lawrence Erlbaum Associates.
Rochat P (1995) *The Self in Infancy: Theory and Research*. New York: Elsevier.
Rosenblum LD (2005) Primacy of multimodal speech perception. In: Pisoni D and Remez R (eds.) *Handbook of Speech Perception*, pp. 51–78. Malden, MA: Blackwell.
Stein BE and Meredith MA (1993) *The Merging of the Senses*. Cambridge, MA: MIT Press.
Walker-Andrews A (1997) Infants' perception of expressive behaviors: Differentiation of multimodal information. *Psychological Bulletin* 121: 437–456.

Relevant Websites

http://www.faculty.ucr.edu – Audiovisual speech web-lab of Dr. Lawrence D. Rosenblum, University of California, Riverside, CA.
http://infantlab.fiu.edu – Infant Development Lab, Dr. Lorraine E. Bahrick, Florida International University, Miami, FL.
http://infantcenter.fiu.edu – Infant Development Research Center; Director Lorraine Bahrick, Co-director, Robert Lickliter, Florida International University, Miami, FL.
http://hincapie.psych.purdue.edu – Infant Lab, Dr. George Hollich, Purdue University, West Lafayette, IN.
http://infantstudies.psych.ubc.ca – Infant Studies Center, Dr. Janet F. Werker, Department of Psychology, University of British Columbia, Vancouver, BC.
http://www.psy.fau.edu – Perceptual Development Lab, Dr. David Lewkowicz, Florida Atlantic University.
http://www.media.mit.edu – Robot word learning; Dr. Deb Roy, MIT, Cambridge MA.
http://kidshealth.org – The Senses and Your Newborn: Nemours Foundation.

L

Language Acquisition Theories

S Goldin-Meadow, University of Chicago, Chicago, IL, USA

Glossary

Canalization – Canalization in genetics is a measure of the ability of a genotype to produce the same phenotype regardless of variability in the environment. More broadly, canalization refers to the developmental path of least resistance, the path typically followed by a species.
Corpus – A large collection of spontaneously produced utterances.
Ergative languages – An ergative language is one in which the subject of an intransitive verb (e.g., 'Elmo' in "Elmo runs home") is treated in grammatical terms (word order, morphological marking) similarly to the patient of a transitive verb (e.g., 'Bert' in 'Elmo hits Bert') and differently from the agent of a transitive verb (e.g., 'Elmo' in 'Elmo hits Bert'). Ergative languages contrast with nominative languages such as English; in English, both the subject of the intransitive verb ('*Elmo* runs home') and the agent of a transitive verb ('*Elmo* hits Bert') are placed before the verb, whereas the patient of a transitive verb is placed after the verb ('Elmo hits *Bert*').
Morpheme – A meaning-bearing linguistic form that cannot be divided into smaller meaning-bearing forms, for example, 'unbearable' is composed of three morphemes, *un*, *bear*, and *able*.
Morphology – The study of how morphemes are combined into stems and words.
Motherese/parentese – The kind of speech that mothers (and others) produce when talking to infants and young children. It is characterized by higher pitches, a wider range of pitches, longer pauses, and shorter phrases than speech addressed to adults (also referred to as child-directed speech or infant-directed speech).
Null-subject languages – Some languages allow pronouns to be omitted from a sentence when the referents of those pronouns can be inferred from context (e.g., Japanese); other languages do not allow pronouns to be dropped (e.g., English). Languages that only allow omission of the subject pronoun are called 'null-subject languages' (e.g., Spanish, Italian).
Predicate – The portion of a clause that expresses something about the subject.
Segmentation – The breaking down of a unit into smaller parts; for example, the word 'dislike' can be broken down into two smaller parts (in this case, morphemes), 'dis' and 'like'.
Specific language impairment – A delay in language development in the absence of any clear sensory or cognitive disorder (as labeled in the *Diagnostic and Statistical Manual of Mental Disorders*, 4th edn.).
Subject – The element in a clause that refers to the most prominent participant in the action of the verb; often (but not always) this participant is the one that does or initiates the action named by the verb.
Syntax – The study of how words combine to form phrases, clauses, and sentences.
Transitional probabilities – A conditionalized statistic which tracks the consistency with which elements occur together and in a particular order, baselined against individual element frequency; for example, if B follows A every time A occurs, the transitional probability for this A–B grouping is 1.00.

Introduction

The simplest technique to study the process of language learning is to do nothing more than watch and listen as children talk. In the earliest studies, researcher parents made diaries of their own child's utterances (e.g., Stern and Stern in the 1900s, and Leopold in the 1940s). The diarist's goal was to write down all of the new utterances that the child produced. Diary studies were later replaced by audio and video samples of talk from a number of children, usually over a period of years. The most famous of these modern studies is Roger Brown's longitudinal recordings of Adam, Eve, and Sarah.

Because transcribing and analyzing child talk is so labor intensive, each individual language acquisition study typically focuses on a small number of children, often interacting with their primary caregiver at home. However, advances in computer technology have made it possible for researchers to share their transcripts of child talk via the computerized Child Language Data Exchange System (CHILDES). A single researcher can now call upon data collected from spontaneous interactions in naturally occurring situations across a wide range of languages, and thus test the robustness of descriptions based on a small sample. In addition, naturalistic observations of children's talk can always be, and often are, supplemented with experimental probes that are used with larger number of subjects.

Thus, it is possible, although time-consuming, to describe what children do when they acquire language. The harder task is to figure out how they do it.

Many theories have been offered to explain how children go about the process of language learning. This article begins by reviewing the major accounts. We will find that, although there is disagreement among the theories in the details, all modern-day accounts accept the fact that children come to the language-learning situation prepared to learn. The disagreement lies in what each theory takes the child to be prepared with: A general outline of what language is? A set of processes that will lead to the acquisition of language (and language alone)? A set of processes that will lead to the acquisition of any skill, including language? The article then goes on to describe theoretical and experimental approaches that have been applied to the problem of determining the constraints that children bring to language learning. We end with an analysis of what it might mean to say that language is innate.

Theoretical Accounts of Language Learning

Behaviorist Accounts

Consistent with the psychological theories of that era, prior to the late 1950s language was considered just another behavior, one that can be acquired by the general laws of behavior. Take, for example, associative learning, a general learning process in which a new response becomes associated with a particular stimulus. Association seems like a natural way to explain how children learn the words of their language, but it is not so simple. Quine's famous theoretical puzzle highlights the problem: Imagine that you are a stranger in a foreign country with no knowledge of the local language. A native says 'gavagai' while pointing at a rabbit running in the distance. You try to associate the new response 'gavagai' with a particular stimulus, but which stimulus should you choose? The entire rabbit? Its tail? Its ears? The running event? The possibilities are limitless and associative learning solves only a small piece of the problem.

In addition to association, imitation, and reinforcement were also proposed as mechanisms by which children could learn the grammatical 'habits' that comprise language. However, even the most cursory look at how children learn language reveals that neither of these mechanisms is sufficient to bring about language learning.

Children learn the language to which they are exposed and, in this broad sense, learn language by imitation. But do children model the sentences they produce after the sentences they hear? Some do, but many children are not imitators. Moreover, the children who are imitators do not learn language any more quickly than the nonimitators. Even the children who routinely imitate do not copy everything they hear – they are selective, imitating only the parts of the sentences that they are able to process at that moment. Thus, imitation is guided as much by the child as by the sentences the child hears.

What about the responses of others to children's sentences? Parents might positively reinforce sentences their children produce that are grammatically correct and negatively reinforce sentences that are grammatically incorrect. In this way, the child might be encouraged to produce correct sentences and discouraged from producing incorrect ones. There are two problems with this account. The first is that parents do not typically respond to their children's sentences as a function of the grammatical correctness of those sentences. Parents tend to respond to the content rather than the form of their children's sentences. Second, even if children's grammatically correct sentences were treated differently from their grammatically incorrect sentences, it is still up to the child to determine what makes the correct sentences correct. For example, if the child says the grammatically correct sentence, "I colored the wall blue," and mother responds with positive reinforcement (thus ignoring the sentence's troubling content and focusing on its form), the child still has to figure out how to generalize from the sentence; she needs to understand the patterns that generate the sentence in order to recognize that one analogous sentence (e.g., "I saw the wall blue") is not grammatically correct while another (e.g., "I pounded the clay flat") is. In other words, there would still be a great deal of inductive work to be done even if children were provided with a set of correct sentences from which to generalize.

The behaviorist account of language was dealt a devastating blow with the publication in 1959 of Noam Chomsky's review of BF Skinner's *Verbal Behavior*. Chomsky argued that adult language use cannot be adequately described in terms of sequences of behaviors or responses. A system of abstract rules underlies each individual's knowledge and use of language, and it is these rules that children acquire when they learn language. When viewed in this way, the language acquisition problem requires an entirely different sort of solution.

Nativist Accounts

The premise of the Chomskian perspective is that children are learning a linguistic system governed by subtle and abstract principles without explicit instruction and, indeed, without enough information from the input to support induction of these particular principles (as opposed to other principles) – Plato's problem or the poverty of the stimulus argument. Chomsky went on to claim that if there is not enough information in the input to explain how children learn language, the process must be supported by innate syntactic knowledge and language-specific learning procedures. The theory of Universal Grammar (UG) formulates this *a priori* knowledge in terms of principles and parameters that determine the set of possible human languages. UG is assumed to be part of the innately endowed knowledge of humans. The principles of UG provide a framework for properties of language, often leaving several (constrained) options open to be decided by the data the child comes in contact with. For example, word order freedom is a parameter of variation. Some languages (English) mandate strict word orders; others (Russian, Japanese) list a small set of admissible orders; still others (Warlpiri, an Australian aboriginal language) allow almost total scrambling of word order within a clause. Input from a given language is needed for learners to set the parameters of that language.

One important aspect of this theory is that setting a single parameter can cause a cluster of superficially unrelated grammatical properties to appear in the language. For example, the null-subject parameter involves a number of properties: whether overt subjects are required in all declarative sentences (yes in English, no in Italian), whether expletive elements such as 'it' in 'it seems' or 'there' in 'there is' are exhibited (yes in English, no in Italian), whether free inversion of subjects is allowed in simple sentences (no in English, yes in Italian), etc. The prediction is that the input necessary to set the null-subject parameter results in the simultaneous alignment of all of these aspects within a child's grammar. There is, at present, controversy over whether predictions of this sort are supported by the child language data.

Innate knowledge of the principles underlying language is, however, not sufficient to account for how children acquire language. How are children to know what a noun or a subject is in the specific language they are learning? Children obviously need to identify subjects and verbs in their language before they can determine whether the two are strictly ordered in that language, and before they can engage whatever innate knowledge they might have about how language is structured. Thus, in addition to innate syntactic knowledge, children also need learning procedures, which may themselves be language-specific.

One example is a set of rules linking semantic and syntactic categories. Under this hypothesis, children are assumed to know innately that agents are likely to be subjects, objects affected by action are likely to be direct objects, etc. All they need do is identify (using context) the agent in a scene; the linking rules allow them to infer that the term used to refer to that agent is the subject of the sentence. Their innate knowledge about how these elements are allowed to be structured can then take over. Again, controversies exist over whether child language data support these assumptions (e.g., ergative languages do not straightforwardly link agents with subjects and yet are easily acquired by young children).

Social/Cognitive Accounts

The nativist position entails essentially two claims: (1) at least some of the principles of organization underlying language are language specific and not shared with other cognitive systems, and (2) the procedures that guide the implementation of these principles are themselves innate, that is, centered in the child and not the child's environment. Note that, while these two claims often go hand-in-hand, they need not. One can imagine that the principles underlying linguistic knowledge might be specific to language and, at the same time, implemented through general, all-purpose learning mechanisms (although such mechanisms must be more complex than the mechanisms behaviorist accounts have offered). This position has come to be known as a social or cognitive account of language learning.

For example, by observing others' actions – where they look, how they stand, how they move their hands and faces – we can often guess their intentions. Young children could use this information to help them narrow down their hypotheses about what a word means. In fact, if a speaker looks at an object while uttering a novel word, a child will assume that the speaker's word refers to that object, even if the child herself is not looking at the object. In other words, children can use general cues to speaker intent to guide their guesses about language.

Children do not sound like adults when they begin to speak – clearly, there is developmental work that needs to be done. The question is what type of work is required? One possibility, favored by some nativists, is that children have in place all of the grammatical categories and syntactic principles they need; they just lack the operating systems that will allow those principles to run. The developmental work to be done does not, under this view, involve a changing grammatical system.

Another view suggests that the child's language changes dramatically during development, transforming from a system based on semantic categories to one based on syntactic categories. This transformation could be determined maturationally or guided by innate linking rules. However, the transformation could also result from an inductive leap children make on the basis of the linguistic data available to them, in conjunction with the cognitive and/or social skills they bring to the task – this inductive leap is at the heart of all social or cognitive accounts of language acquisition.

Cognitive underpinnings are obviously necessary but they may not be sufficient for the onset of linguistic skills. For example, the onset of gesture plus speech combinations that convey two elements of a proposition ('open' plus point at box) precedes the onset of two-word combinations ('open box') by several months, suggesting that the cognitive ability to express two semantic elements is not the final stumbling block to two-word combinations. More than likely, it is the inability to extract linguistic patterns from the input that presents the largest problem.

Social and cognitive accounts claim that there is, in the end, enough information in the linguistic input children hear, particularly in the context of the supportive social environments in which they live, to induce a grammatical system. Ample research indicates that adults alter the speech they direct to their children. Speech to children (often called 'motherese') is slower, shorter, higher-pitched, more exaggerated in intonation, more grammatically well-formed, and more directed in content to the present situation than speech addressed to adults. And children pay particular attention to this fine-tuned input, interpreting it in terms of their own biases or operating principles (e.g., paying attention to the ends of words).

However, one problem that arises with postulating motherese as an engine of child language learning is that child-directed speech may not be universal. In many cultures, children participate in communicative interactions as overhearers (rather than as addressees) and the speech they hear is not likely to be simplified in the same ways. Nevertheless, children in these cultures become competent users of their grammatical systems in roughly comparable timeframes. These observations suggest that there may be many developmental routes to the same end – a reasonable conjecture given the robustness of language.

One very interesting possibility that skirts the problem that children do not universally receive simplified input is that the children may do the simplifying themselves. For example, young children's memory limitations may make them less able to recall entire strings of words or morphemes. They would, as a result, be doing the analytic work required to abstract linguistic regularities on a smaller, filtered database (the 'less is more' hypothesis). This filtering may be just what children require to arrive at their linguistic systems. Moreover, it is a general process that children around the globe presumably bring, in equal measure, to the language-learning situation.

Connectionist Accounts

Connectionism is a movement in cognitive science whose goal is to explain human intellectual abilities using artificial neural networks (also known as neural nets). Neural networks are simplified models of the brain composed of large numbers of units (the analogs of neurons) and weights that measure the strength of the connections between those units. In a connectionist account, behavior is shaped by selective reinforcement of the network of interconnected units. Under this view, language development is a process of continuously adjusting the relative strengths of the connections in the network until linguistic output resembles linguistic input.

In a sense, connectionism is more of a technique for exploring language learning than an explanatory account. But connectionism does come with some theoretical baggage. For example, most connectionist models are based on the assumption that language (like all other cognitive skills) can be explained without recourse to rules.

Connectionism offers a tool for examining the tradeoff between the three components central to all theories of language learning – environment (input to the system), structures the child brings to the learning situation (architectures of the artificial system), and learning mechanisms (learning algorithms). For example, a great deal of linguistic structure is assumed to be innate on the nativist account. Connectionism can provide a way to explore how much structure needs to be built in to achieve learning, given a particular set of inputs to the system and a particular set of learning mechanisms. As another example, networks have been shown to arrive at appropriate generalizations from strings of sentences only if the memory span of the network for previously processed words begins small and gradually increases (reminiscent of the 'less is more' hypothesis described earlier). In principle, connectionism is agnostic on the question of whether the architecture of the system (the child) or the input to the system (the environment) determines the relative strengths of each connection. However, in practice, most connectionists emphasize the importance of input. And, of course, the unanswered question is what determines the units that are to be connected in the first place.

Constrained Learning

All theoretical accounts agree that human children are prepared to learn language. But what are they prepared with? Do children come to the learning situation with specific hypotheses about how language ought to be structured? Or do they come with general biases to process information in a particular way? This second view suggests that the strong inclination that children have to structure communication in language-like patterns falls out of their general processing biases coming into contact with natural language input.

The language that children learn must, at some level, be inferable from the data that are out there. After all, if linguists manage to use language data to figure out the grammar of a language, why can't children? But linguists can be selective in ways that children are not able to be. Linguists do not have to weigh all pieces of data equally, they can ask informants what an utterance means and whether it is said correctly, and they have at their disposal a great deal of data at one time. The question is – what kinds of learning mechanisms can we realistically impute to children that will allow them to make sense of the data they receive as input?

One learning mechanism that has been proposed is known as statistical learning. The assumption underlying this mechanism is that children are sensitive to the patterns in their input, and can perform rapid and complex computations of the co-occurrences among neighboring elements in that input. By performing statistical computations over a corpus, children can pick out the recurring patterns in the data and thus are less likely to be misled by individual counter-examples.

However, children must also face the problem that a corpus can be analyzed in many different ways. How do they know which computations to perform on a given corpus? Perhaps children are only able to perform a limited set of computations. If so, this limitation would effectively narrow down the range of possible patterns that could be extracted from a database. Thus, one way that children may be prepared to learn language is that they come to language learning ready to perform certain types of computations and not others.

To discover which computations young language learning children are able to perform, we can provide them with a corpus of data constructed to exhibit a pattern that can be discovered using a particular computation. If the children then extract the pattern from the data, we know that they are able to perform this type of computation on a corpus. As an example, 8-month-old infants were exposed to a corpus of nonsense words playing continuously on an audiotape for 2 min. The corpus was arranged so that the transitional probabilities between sounds were 1.0 inside words, but 0.33 across words. The only way the infant could figure out what the words in the corpus were was to (1) pay attention to these transitional probabilities and (2) assume that sequences with high probabilities are likely to be inside words and that sequences with low probabilities are likely to be the accidental juxtapositions of sounds at word boundaries. The infants not only listened differentially to words vs. nonwords, but they were able to discriminate between words and part-words (part-words contained the final syllable of one word and the first two syllables of another word; they were thus part of the corpus the infants heard but had different transitional probabilities from the words). The 8-month-olds were not merely noting whether a syllable sequence occurred – they were inducing a pattern from the sounds they had heard, and using a mechanism that calculates statistical frequencies from input to do so.

Infants are thus sensitive to the transitional probabilities between sounds and can use them to segment speech into word-like units. Can this simple mechanism be used as an entry point into higher levels of linguistic structure? If, for example, children can use transitional probabilities between words (or word classes) to segment sentences into phrases, they could then use this phrasal information as a wedge into the syntax of their language. In other words, children may be able to go a long way toward inducing the structure of the language they are learning by applying a simple procedure (tabulating statistical frequencies) to the data that they receive. A related domain-general approach that has been taken to the problem is the Bayesian inference framework, a tool for combining prior knowledge (probabilistic versions of constraints) and observational data (statistical information in the input) in a rational inference process. The theoretical assumption underlying all of these approaches is that children come to language learning equipped with processing strategies that allow them to induce patterns from the data to which they are exposed.

The open question at the moment is – how sophisticated do the data-processing strategies have to be in order for children to induce the patterns of their language from the input that they actually receive? Can children get by with the ability to calculate transitional probabilities, building up larger and larger units over developmental time? Or are there units over which children are more, or less, likely to calculate transitional probabilities? For example, children may (or may not) be able to calculate statistical probabilities over units that are not immediately adjacent (i.e., dependencies between units that are at a distance from one another, for instance, in the sentence, 'the cats on the couch are beautiful,' the verb 'are' is plural because it depends on 'cats', the subject of the sentence, which occurs several words earlier). Some of the constraints that children exhibit during language learning may come from the processing mechanisms they bring to the situation.

Two questions are frequently asked about language processing mechanisms. (1) The task-specificity question – are the mechanisms that children apply to language learning unique to language, or are they used in other domains as well? (2) The species-specificity question – are the mechanisms children apply to language learning unique to humans, or are they used by other species as well?

The task-specificity question can be addressed with respect to statistical learning by providing children with nonlanguage input that is patterned (e.g., musical patterns, visual patterns) and observing whether young infants can discover those patterns. They do, suggesting that calculating transitional probabilities is a general purpose data-processing mechanism that children apply to their worlds. The species-specificity question can be addressed with respect to statistical learning by exposing nonhumans to the same type of language input that the human infants heard, and observing whether they can discover the patterns. It turns out that cotton-top tamarin monkeys can extract word-like units from a stream of speech sounds just as human infants do. But, of course, tamarin monkeys do not acquire human language. The interesting question, then, is where do the monkeys fall off? What types of computations are impossible for them to perform? This theoretically motivated paradigm thus allows us to determine how the mechanisms children bring to language constrain what they learn, and whether those constraints are specific to language and specific to humans.

Constrained Invention

When children apply their data-processing mechanisms to linguistic input, the product of their learning is language. But what if a child was not exposed to linguistic input? Would such a child be able to invent a communication system and, if so, would that communication system resemble language? If children are able to invent a communication system that is structured in language-like ways, we must then ask whether the constraints that guide language learning are the same as the constraints that guide language invention.

Language was clearly invented at some point in the past and was then transmitted from generation to generation. Was it a one-time invention, requiring just the right assembly of factors, or is language so central to being human that it can be invented anew by each generation? This is a question that seems impossible to answer – today's children do not typically have the opportunity to invent a language, as they are all exposed from birth (and perhaps even before birth since babies can perceive some sounds *in utero*) to the language of their community. The only way to address the question is to find children who have not been exposed to a human language.

In fact, there are children who are unable to take advantage of the language to which they are exposed. These children are congenitally deaf with hearing losses so severe that they cannot acquire the spoken language that surrounds them, even with intensive instruction. Moreover, they are born to hearing parents who do not know a sign language and have not placed their children in a situation where they would be exposed to one. These children lack an accessible model for human language. Do they invent one?

The short answer is yes. The children are able to communicate with the hearing individuals in their worlds, and use gesture to do so. This is hardly surprising since all hearing speakers gesture when they talk. The surprising result is that the deaf children's gestures do not look like the gestures that their hearing parents produce. The children's gestures have language-like structure; the parents' gestures do not.

The children combine gestures, which are themselves composed of parts (akin to morphemes in conventional sign languages), into sentence-like strings that are structured with grammatical rules for deletion and order. For example, to ask an adult to share a snack, one child pointed at the snack, gestured eat (a quick jab of an O-shaped hand at his mouth), and then pointed at the adult. He typically placed gestures for the object of an action before gestures for the action, and gestures for the agent of an action after. Importantly, the children's gesture systems are generative – the children concatenate gestures conveying several propositions within the bounds of a single-gesture sentence. For example, one child produced several propositions about snow shovels within a single sentence: that they are used to dig, that they are used when boots are worn, that they are used outside, and kept downstairs. The gesture systems have parts of speech (nouns, verbs, adjectives), are used to make generic statements (as in the snow shovel example), and are used to tell stories about the past, present, future, and the hypothetical. The children even use their gestures to talk to themselves and to talk about their own gestures.

In contrast, the children's hearing parents use their gestures as all speakers do. Their sloppily formed gestures are synchronized with speech and are rarely combined with one another. The gestures speakers produce are meaningful, but they convey their meanings holistically, with no componential parts and no hierarchical structure.

The theoretically interesting finding is not that the deaf children communicate with their gestures, but that their gestures are structured in language-like ways. Indeed, the children's gestures are sufficiently language-like that they have been called home signs. It is important to note that the deaf children could have used mime to communicate – for example, miming eating a snack to invite the adult to join the activity. But they do not. Instead, they produce discrete, well-formed gestures that look more like beads on a string than a continuous unsegmentable movement.

Segmentation and combination are at the heart of human language, and they form the foundation of the deaf children's gesture systems. But segmentation and combination are not found in the gestural input children receive from their hearing parents. Thus, the deaf children could not easily have taken data-processing strategies of the sort that have been hypothesized and applied them to the gestural input they receive in order to arrive at their home-sign systems. Although it is clear that children must be applying data-processing strategies to the particular language they hear in order to acquire that language, it is equally clear that children can arrive at a language-like system through other routes. A communication system structured in language-like ways seems to be overdetermined in humans.

The deaf children invented the rudiments of language without a model to guide them. But they did not invent a full-blown linguistic system – perhaps for good reason. Their parents wanted them to learn to talk and thus did not share the children's gesture systems with them. As a result, the children's systems were one-sided; they produced language-like gestures to their parents, but received nonlinguistic co-speech gestures in return.

What would happen if such a deaf child were given a partner with whom to develop language? Just such a situation arose in the 1980s in Nicaragua when deaf children were brought together in a group for the very first time. The deaf children had been born to hearing parents and, like the deaf children described above, presumably had invented gesture systems in their individual homes. When they were brought together, they needed to develop a common sign language, which has come to be called Nicaraguan Sign Language (NSL). The distance between the home signs invented by individual children without a partner and the sign system created by this first cohort of NSL can tell us which linguistic properties require a shared community in order to be introduced into human language.

But NSL has not stopped growing. Every year, new deaf children enter the group and learn to sign among their peers. This second cohort of signers has as its input the sign system developed by the first cohort. Interestingly, second-cohort signers continue to adapt the system so that the product becomes even more language-like. The properties of language that crop up in this second and subsequent cohorts are properties that depend on passing the system through fresh minds – linguistic properties that must be transmitted from one generation to the next in order to be introduced into human language.

NSL is not unique among sign languages; it is likely that all sign languages came about through a similar process. As another recent example, a community was founded 200 years ago by the Al-Sayyid Bedouins. Two of the founders' five sons were deaf and, within the last three generations, 150 deaf individuals have been born into the community. Al-Sayyid Bedouin Sign Language (ABSL) was thus born. ABSL differs from NSL in that it is developing in a socially stable community with children learning the system from their parents. Because ABSL is changing over time, the signers from each of the three generations are likely to differ, and to differ systematically, in the system of signs they use. By observing signers from each generation, we can therefore make good guesses as to when a particular linguistic property first entered the language. Moreover, because the individual families in the community are tightly knit, with strong bonds within families but not across them, we can chart changes in the language in relation to the social network of the community. We can determine when properties remained within a single family and when they did not, and thus follow the trajectory that particular linguistic properties took as they spread (or failed to spread) throughout the community. This small and self-contained community consequently offers a unique perspective on some classic questions in historical linguistics.

Because sign languages are processed by eye and hand rather than ear and mouth, we might have expected them to be structured differently from spoken languages. But they are not. Sign languages all over the world are characterized by the same hierarchy of linguistic structures (syntax, morphology, phonology) and thus draw on the same human abilities as spoken languages. Moreover, children exposed to sign language from birth acquire that language as naturally as hearing children acquire the spoken language to which they are exposed, achieving major milestones at approximately the same ages.

However, the manual modality makes sign languages unique in at least one respect. It is easy to use the manual modality to invent representational forms that can be immediately understood by naive observers (e.g., indexical pointing gestures, iconic gestures). Thus, sign languages can be created anew by individuals and groups, and are particularly useful in allowing us to determine whether language-creation is constrained in the same ways that language learning is.

Computational and robotic experiments offer another approach to the problem of language invention. These studies explore whether communication systems with properties akin to those found in natural human language can emerge in populations of initially language-less agents. There are two traditions in this work. The first functional approach assumes that linguistic structure arises as a solution to the problem of communication, for example, as a way of limiting search through possible interpretations. The second structural approach does not rely on communication pressure to motivate change but rather examines the emergence of structure as the system is passed from one user (or one generation of users) to the next. Studies in this second tradition have found that a compositional system with recursion, grammatical categories, and word order inevitably results from passing an initially unstructured communication system through generations of learners. These are just the properties found in the deaf children's home-sign gesture systems, but the home-sign systems are not passed through a series of learners and are instead invented by individual children who are the sole users of their systems. Once again, we find that there is more than one way to arrive at language-like structure. In general, modeling studies, combined with observations of actual cases of language learning and language invention, can help us appreciate the range of circumstances under which language-like structure can arise and the mechanisms responsible for that structure.

Is Language Innate?

Children are likely to come to language learning constrained to process the language data they receive in certain ways and not in others. The constraints could be specifically linguistic, but they need not be. Constraints are assumed to be internal to the child at the moment when a particular skill is acquired. But are they innate?

Innateness Defined as Genetic Encoding

The problem of innateness has been addressed repeatedly and elegantly in other disciplines, especially ethology, and many definitions of innateness have been proposed. One of the most common, albeit not the earliest, definitions of an innate behavior is that it have a genetic base. Some have claimed evidence for grammar genes – not for a single gene responsible for all the circuitry underlying grammar but for a set of genes whose effects are relevant to the development of the circuits underlying parts of grammar. The dispute is whether the genes are specific to the grammatical aspects of language.

What might it mean to claim that language has a genetic base? At one level, the claim is obviously true – equipped with the human genetic potential, humans develop language. But what does this claim buy us if our interest is in understanding how children learn language? We could study twins, both fraternal and identical, to explore the phenomenon of language learning. However, in this regard, it is important to note that, in twin studies conducted to explore the genetic basis of intelligence (i.e., IQ), the focus is on differences among individuals relative to a normative scale. In contrast, claims about the innateness of language are claims about the commonalities among people, not the genetic differences between people. In arguing that language is genetically based, there is no obvious claim that two individuals who are genetically related have linguistic systems that are more alike than two individuals who are not genetically related. All humans who are genetically intact have, at base, comparable linguistic systems – comparable in the same way that all human bodies have two arms and two legs. The details of the arms of any two unrelated individuals (their length, width, definition, etc.) are likely to differ (and those differences may or may not be grounded at the genetic level) but the basic twoness and structure of the arm is constant across all genetically intact humans – so too for language.

So why then (assuming we are not geneticists) should we care about the genetic base of language learning? Perhaps we should not. Of all of the very large number of definitions and criteria that have, over the years and over the disciplines, been applied to the term innate, one could argue that the definition that is least central to the notion's core is having a genetic base. A useful definition of innate need not be anchored in genetic mechanisms.

Innateness Defined as Developmental Resilience

An alternative definition of an innate behavior is that it is developmentally resilient. A behavior is developmentally resilient if its development, if not inevitable, is overdetermined in the species; that is, it is a behavior likely to be developed by each member of the species even under widely varying circumstances. The way we traditionally explore the boundaries for the development of a behavior is to manipulate the conditions under which that behavior is typically developed, extending the range until the behavior no longer appears. For obvious ethical reasons, we cannot tamper with the circumstances under which children learn language. But we can take advantage of variations in language-learning conditions that occur naturally, and thus explore the boundary conditions under which language development is possible.

Resilience in the face of external variation

Language learning is not infinitely resilient. When human children are raised by animals, they do not develop language. And when children are raised by inhumane parents who mistreat them physically and emotionally, including depriving them of a model for language, they do not develop language. But given a reasonable social world, children seem to be able to develop language under a wide range of circumstances.

Consider first the effects of variability in the way adults speak to children within a culture. Adults in each culture tend to use a distinct register of speech with their children. There is, however, variability across adults in how much they talk to their children and in the frequency with which certain constructions are used. Variability in the amount of talk a child hears has been shown to affect that child's rate of vocabulary growth, and variability in how often a particular construction is used in speech to a child has been shown to affect how quickly the child develops that construction. However, despite the effects of input on the pacing of language learning, there is no evidence that the particular way in which an adult speaks to a child affects whether or not language is ultimately learned by that child.

Indeed, the amount of input a child receives can be quite minimal and still the child will learn language. For example, hearing children born to deaf parents often get very minimal exposure to speech. But it turns out that they do not need much; 5–10 h a week of exposure to hearing speakers is typically sufficient to allow language learning to proceed normally. As another example, twins share their language-learning situation with one another, making the typical adult-twin situation triadic rather than dyadic. Nonetheless, language learning proceeds along a normal trajectory, although often with mild delays. A child may develop language more or less quickly, but almost all intact children in almost all linguistic environments eventually develop language.

The resilience of language learning in the face of across-culture variability is even more impressive. Cultures hold different beliefs about the role that parents need to play to ensure the child's acquisition of language. Not surprisingly, then, children around the globe differ in how much, when, and what types of language they receive – not to mention the fact that, in each culture, the child is exposed to a model of a different language. Indeed, many children are exposed to input from two different languages and must learn both at the same time. Despite the broad range of inputs, children in all corners of the earth learn language and at approximately the same pace.

Resilience in the face of internal variation

Language learning is also resilient in the face of many organic variations from the norm, variations that alter the way children process whatever input they receive. For example, intermittent conductive hearing losses from repeated middle ear infections can cause a child's intake of linguistic input to vary over time in amount and pattern. Despite this variability, spoken language development for the most part proceeds normally in children with this type of hearing loss. As a second example, blind children live in a nonvisual world that is obviously different from the sighted child's world, and that offers a different spectrum of contextual cues to meaning. However, this difference has little impact on language learning in the blind child.

Organic variation can be much more severe and still result in relatively intact language learning. For example, grammar learning in the earliest stages can proceed in a relatively normal manner and at a normal rate even in the face of unilateral ischemic brain injury. As a second example, children with Down syndrome have numerous intrinsic deficiencies that complicate the process of language acquisition. Nevertheless, most Down syndrome children acquire some basic language reflecting the fundamental grammatical organization of the language they are exposed to (the amount of language that is acquired is in general proportion to their cognitive capabilities). Finally, and strikingly, given the social impairments that are at the core of the syndrome, autistic children who are able to learn language are not impaired in their grammatical development, either in syntax or in morphology, although they do often have deficits in the communicative, pragmatic, and functional aspects of their language.

Interestingly, even when children do have trouble learning language, some properties of language (the resilient ones) are spared. For example, a basic understanding of the organization that underlies predicates appears to be intact in children with specific language impairment (children who have neither hearing impairment, cognitive deficit, nor neurological damage yet fail to develop language normally). However, these children have difficulty with morphological constructions. As another example, children who are not exposed to a usable language until adolescence have no trouble mastering word order when learning language late in life, but do have difficulty with morphology. Some properties of language appear to be robust, and some fragile, across a variety of circumstances and internal states.

There may be no greater testament to the resilience of language than the fact that children can invent language in the absence of a model for language. A combination of internal factors (the fact that the children are profoundly deaf and cannot acquire a spoken language) and external factors (the fact that the children have not been exposed to a conventional sign language) together create the unusual language-learning circumstances in which the deaf children described earlier find themselves. Despite their lack of a model for language, these children still communicate in language-like ways.

In sum, language development can proceed in humans over a wide range of environments and a wide range of organic states, suggesting that the process of language development may be buffered against a large number of both environmental and organic variations. No one factor seems to be ultimately responsible for the course and outcome of language development in humans, a not-so-surprising result given the complexity and importance of human language.

Mechanisms that Could Lead to Resilience

Another way of describing the language-learning process is that the range of possible outcomes in the process is narrowed. This narrowing or canalization is often attributed to genetic causes. However, canalization can also be caused by the environment. Consider an example from another species. 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 responding to that stimulus, and buffered against responding to other stimuli. Note that, in order for acquisition to be universal when the environment is playing a canalizing role, the relevant aspect of the environment must be reliably present in the world of each member of the species. In a sense, the environment must be considered as much a part of the species as its genes.

For language, it looks as though there is a basic, resilient form that human communication naturally gravitates toward, and a variety of developmental paths that can be taken to arrive at that form. In this sense, language development in humans can be said to be characterized by equifinality, an embryological term coined to describe a process by which a system reaches the same outcome despite widely differing input conditions. No matter where you start, all roads lead to Rome.

Are there any implications for the mechanisms of development that we can draw once having identified language as a trait characterized by equifinality? Two types of systems seem possible:

1. A system characterized by equifinality can rely on a single developmental mechanism that not only can make effective use of a wide range of inputs (both external and internal) but will not veer off track in response to that variability, that is, a mechanism that is not sensitive to large differences in input. The gross image that comes to mind here is a sausage machine that takes inputs of all sorts and, regardless of the type and quality of that input, creates the same product.
2. A system characterized by equifinality can rely on multiple developmental mechanisms, each activated by different conditions but constrained in some way to lead to the same end product. The analogy here is to several distinct machines, each one designed to operate only when activated by a particular type of input (e.g., a chicken, pig, cow, or turkey). Despite the different processes that characterize the dismembering operations of each machine, the machines result in the same sausage product. At first glance, it may seem improbable that a variety of developmental mechanisms would be constrained to arrive at precisely the same outcome. However, it is relatively easy to imagine that the function served by the mechanisms – a function that all of the developmental trajectories would share – might have been sufficient to, over time, constrain each of the mechanisms to produce the same product. Communicating via symbols with other humans might be a sufficiently constraining function to result in several mechanisms, each producing language-like structure.

Which of these scenarios characterizes what actually happens when children learn language is an open question. But what is clear is that language-like structure is overdetermined in human children. Many paths lead to the same outcome, and whatever developmental mechanism we propose to explain language learning (or language invention) is going to have to be able to account for this equifinality.

Language is Not a Unitary Phenomenon

Until now we have been discussing language as though it were a unitary phenomenon, as though it were obvious what the appropriate unit of analysis for language is. However, it is clear that language is not a unitary whole, particularly when it comes to issues of resilience and innateness.

Children who are not exposed to a conventional language model create communication systems that contain some, but not all, of the properties found in natural human languages. Thus, the absence of a conventional language model appears to affect some properties of language more than others. Even when linguistic input is present, it is more likely to affect rate of acquisition for certain properties of language than for others. Further, when language is acquired off-time (i.e., in late childhood or adolescence) certain properties of language are likely to be acquired and others are not. Thus, some properties of language are relatively resilient, while others are relatively fragile. Moreover, there is some evidence that the same properties of language (e.g., using the order of words to convey who does what to whom) are resilient across many different circumstances of acquisition – acquisition without a conventional language model, with varying input from a language model, and late in development after puberty. Thus, language as a whole need not be said to be innate.

The definition of innate that best fits the language-learning data is developmental resilience. This notion operationalizes innateness by specifying the range of organisms and environments in which language learning can take place. There clearly are limits on the process of language development; children raised without human interaction do not develop language. But the process of language development can proceed in children with a range of limitations and in children raised in environments that vary radically from the typical. What we see in exploring this resilience is that certain aspects of language are central to humans – so central that their development is virtually guaranteed, not necessarily by a particular gene but by a variety of combinations of genetic and environmental factors. In this sense, language is innate.

See also: Bilingualism; Grammar; Imitation and Modeling; Language Development: Overview; Learning; Literacy; Pragmatic Development; Preverbal Development and Speech Perception; Semantic Development; Speech Perception.

Suggested Readings

Bishop D and and Mogford K (eds.) (1988) *Language Development in Exceptional Circumstances.* New York: Churchill Livingtone.
Bloom P (ed.) (1993) *Language Acquisition: Core Readings.* New York: Harvester Wheatsheaf.
Brown R (1973) *A First Language.* Cambridge, MA: Harvard University Press.
Fletcher P and and Mac Whinney B (eds.) (1995) *The Handbook of Child Language.* Oxford: Blackwell Publishers.
Gleitman LR and Newport EL (1995) The invention of language by children: Environmental and biological influences on the acquisition of language. In: Gleitman LR and Liberman M (eds.) *Language Vol. 1, Invitation to Cognitive Science Series*, pp. 1–24. Cambridge, MA: MIT Press.
Goldin-Meadow S (2003) *The Resilience of Language: What Gesture Creation in Deaf Children Can Tell Us About How All Children Learn Language.* New York: Psychology Press.
Lust BC and and Foley C (eds.) (2004) *First Language Acquisition: The Essential Readings.* Oxford: Blackwell.
Mac Whinney B (ed.) (1987) *Mechanisms of Language Acquisition.* Hillsdale, NJ: Erlbaum.
Pinker S (1994) *The Language Instinct: How the Mind Creates Language.* New York: Morrow.
Slobin DI (ed.) (1985–1997) *A Cross-Linguistic Study of Language Acquisition,* vols 1–5. Hillsdale, NJ: Erlbaum Associates.
Tager-Flusberg H (ed.) (1994) *Constraints on Language Acquisition: Studies of Atypical Children.* Hillsdale, NJ: Erlbaum Associates.
Wanner E and and Gleitman LR (eds.) (1982) *Language Acquisition: The State of the Art.* New York: Cambridge University Press.

Language Development: Overview

E Lieven, Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany

Glossary

Grammar – The study of classes of words, their inflections, and their functions and relations in a sentence.
Morphology – The system of word-forming elements and processes in a language.
Phonology – The study of speech sounds.
Semartics – The study of the meaning of words.
Syntax – The way in which words are put together to form phrases, clauses, or sentences.

Introduction

All over the world, children learn to talk on a roughly equivalent timetable. They do so by learning the language or languages of their environment. There is considerable debate over what cognitive, social, or specifically linguistic, innate capacities they bring to language leaning. This article begins with a brief timetable of development and then focuses in turn on the major aspects of language learning in terms of infancy, learning words, learning morphology, early grammar, later grammar, and the learning of pragmatic and metalinguistic skills. It concludes with some brief reflections on atypical development. The relevant theoretical issues are covered as they arise in each section and are considered again in the last section on learnability and constituency.

During infancy, children develop a wide range of cognitive and social skills together with a developing ability to segment the speechstream into meaningful units. They usually produce their first recognizable words somewhere between 10–18 months of age and their first multiword utterances between 14–24 months. By age 3 years, children are often able to produce quite long utterances and are beginning to be able to combine more than one clause into coordinate and subordinate constructions (e.g., relative clauses, cleft sentences). Between the ages of 4 to 7 years, there are major advances in children's ability to take the perspective of the listener into account and to produce coherent discourse and narrative sequences. These abilities, as well as the ability to reflect on language as an object of knowledge, develop throughout the school years and are much influenced by the extent of literacy or other complex language (for instance, ritual language) to which children are exposed.

Throughout this developmental timetable, there are major individual differences in the ages at which children reach these points and, in addition, in the balance of skills that a particular child may manifest at a particular point in time. There are also individual differences in how children tackle any of these tasks. This is an important point to remember when considering theories that rely for their confirmation on a particular order of development or on a particular relationship among different skills. It is also important to remember that many children (perhaps most) grow up hearing and, to some extent at least, learning more than one language. The evidence to date is that doing so does not have a significant impact on the developmental timetable for language learning in the early years.

Overview of Development

Infancy

Children are born with the ability to discriminate their mother's voice from that of other women and to discriminate speech from nonspeech, presumably because of their