



LANGUAGE

All human communities have, and use, *language*. Language allows humans to refer to objects, properties, actions, abstract entities, and other aspects of the world, and to convey and retrieve thoughts in a way that seems both fast and effortless. Both in its complexity and internal structure and in its expressive power, human language is well beyond any communicative system available to nonhumans. This entry surveys some basic empirical evidence and theorizing about the nature and properties of human language, the way language is produced and understood, and the way language is acquired by children.

The Nature of Language

Even though there are about 4,000 languages in the world today, they all share major design features that characterize the human faculty of language in general. One such design feature is creativity: Speakers of a language can produce and understand sentences that they have never uttered or heard before. For instance, it is possible to understand the meaning of the sentence *Napoleon never went to the moon* (and agree that the sentence expresses something true) without ever having encountered this sentence before. This shows that the human language ability does not rest on memorizing and storing linguistic strings but, rather, involves drawing on the finite number of items in one's vocabulary and combining them in

novel and systematic ways to form a potentially infinite number of new sentences.

A second design feature of language is structure: Structural principles and rules constrain the kind of sentences that speakers can generate. Language involves several interconnected levels, from sound to syntax to meaning, and each level is governed by a specialized set of rules. For instance, one rule governing the sound structure of English specifies that the sequence *tl* cannot be used in the beginning of a new word (this is why *Tlong* is an unlikely name for a new cartoon character but *Klong* is not). Another kind of rule specifies the relative position of adjectives and nouns (*red umbrella* is an acceptable English phrase but *umbrella red* is not). A major goal for formal theories of language has been to discover the full set of principles underlying human languages. Following the work of Noam Chomsky, a further goal for many theorists has been to identify a core set of such basic principles (otherwise known as universal grammar) that can serve as the innate basis for all human languages.

The Production and Comprehension of Language

Humans can comfortably produce speech at the rate of four words per second, and comprehension follows the speed of production. Even though speaking and understanding speech seem effortless, both processes are supported by complex cognitive machinery.

Speaking involves multiple overlapping stages beginning with the intention to convey a message

and ending with the formulation and execution of a sentence encoding that message. Speakers work in a top-down way, first deciding what they want to express, then choosing words and structures to communicate their message, and finally programming the implementation of the linguistic stimulus on the sound level so they can articulate it. The least well understood of these phases is the process of message preparation: Although this stage includes nonlinguistic apprehension of events and objects (and therefore interfaces with perceptual/conceptual representations of the world), the precise form of these nonlinguistic representations remains elusive.

More is known about the processes underlying the selection and assembly of words and sounds of a sentence. Evidence from several laboratories points to some degree of independence between the word- and sound-combining levels of speech planning: For instance, the tip-of-the-tongue phenomenon (the familiar sense that we cannot retrieve a word that we know) reveals that speakers can access information about the grammatical class of a word (e.g., whether it is a noun or verb) without accessing information about how the word sounds. Further evidence for the systems underlying language production comes from speech errors (or slips of the tongue). Such errors reveal rule-like constraints in how words or sounds are arranged when we prepare speech. For instance, when words switch places during a slip of the tongue, they almost always exchange with other words from the same grammatical class (nouns, verbs, etc.; e.g., *swimmers sink* becomes *swimmers drown*). When sounds switch places, they almost always exchange with other sounds of the same class of linguistic sounds (vowels or consonants; e.g., *snow flurries* becomes *flow snurries*). Thus, even speech errors seem to involve principled choices over abstract representations on the word or sound level—thereby offering indirect evidence for similar mechanisms in regular, error-free production. Such errors further demonstrate that speaking involves the active construction of utterances “on the fly” from smaller linguistic units.

Language comprehension (or *parsing*, as it is often called), unlike production, might appear to work in a bottom-up way: hearers are often thought to start with the sounds they hear, then identify the words and group them into structures,

and proceed to infer what the speaker meant by a sentence. However, evidence indicates top-down influences on parsing because hearers may bring real-world knowledge or expectations about what speakers are trying to do to bear on the ongoing interpretation of an utterance. For instance, when people are placed at a table with several objects on it and are asked *Pick up the candle*, they move their eye gaze to the candle before they reach to perform the requested action. These spontaneous eye movements are a good measure of people’s interpretation of incoming linguistic material. It turns out that hearers start looking at the candle approximately 50 milliseconds (ms) before the end of the word *candle*. But if there is candy on the table along with the candle, eye movements to the candle start only 30 ms after the end of the *candle*. This shows that auditory information as well as contextual information (the specific objects in a scene) affects word identification.

Similar evidence exists for structure identification. Consider a sentence that begins as follows: *Put the apple on the towel . . .* This may mean either that the apple should be placed on the towel, or that the apple that is on the towel should be placed in some location (to be specified in the rest of the sentence). In the absence of context, listeners prefer the first interpretation (e.g., if the sentence continues with . . . *into the box*, listeners become temporarily confused). But when placed at a table with two apples, one of which is on a towel and the other on a napkin, listeners’ eye movements show that they access the second interpretation from the beginning (sentence continuations with . . . *into the box* cause no comprehension problems). During the interpretation of a sentence, then, syntactic, lexical, and contextual factors are rapidly integrated and affect the process of grouping words into linguistic structures. This example illustrates how the context provided by perception of a scene can play a role in this process of linguistic grouping.

As this and other experimental evidence shows, language comprehension is incremental: When hearers encounter a sentence, they begin to incorporate incoming words into a growing, richly structured representation of the sentence (rather than store them as a list and wait for the end of the sentence to recover the structure). Furthermore, hearers attempt to connect this representation of the sentence to the world around them. The precise way in

which syntactic, lexical, and contextual factors affect parsing, as well as the way in which the language comprehension processes coordinate with the systems underlying language production, remain major questions in the psychology of language.

The Acquisition of Language

All human beings, under normal rearing circumstances, acquire language. Language learning begins at birth, if not earlier. Newborns are able to discriminate between possible sounds of human languages, even when these sounds do not belong to their native languages. Around the first year, as children begin to acquire the sound system of their native tongues, the ability to distinguish between foreign sounds is mostly lost. Children can understand certain words as early as 9 months, and they start producing words around their first birthday. First words (mostly, names for objects or individuals) are used in isolation and later in simple (two-word) sentences. Around the age of 2 or 3, grammatical markers (such as *-ed* and *-ing* in English) appear and the rate and diversity of vocabulary grows (with verbs, adjectives, and other terms being added). Between the ages of 3 and 5, children's sentences increase in length and complexity; a typical 5-year-old already knows about 10 to 15 thousand words.

The acquisition of language seems to take place fast, effortlessly, accurately, and mostly without explicit instruction from adults. Children can acquire language even in societies where no language is directed to infants before infants themselves speak. How is this feat accomplished? Part of the answer is that language learning requires the discovery of regularities on multiple levels of the linguistic input, and evidence shows that even very young infants are sensitive to linguistic patterns (such as recurring sound sequences). However, most theorists agree that children's search for patterns in the linguistic input has to be guided by strong biological influences. Several arguments support this position. First, universal properties of language surface in all the languages that have been studied so far. For example, linguistic sentences always include a subject (even though in some languages such as Greek, the subject is not overtly pronounced but is understood from the form of verb: *Efiga htes* = "[I]-left yesterday"). Second, as

described, language acquisition seems to proceed universally through the same stages for all learners despite differences in culture, socioeconomic level, parenting style, motivation, and other factors in the learners' environment. Additionally, linguistic abilities seem to be specialized and often dissociate from general-cognitive abilities in pathology. For instance, children with Williams syndrome, whose IQs are below normal, have intact language-learning capacities; children with specific language impairment are characterized by deficits in the time-line and nature of their language learning, even though their IQs are within the normal range.

Some of the most compelling evidence for humans' biological preparedness for language comes from the resilience of language learning given absent or degraded input. Children who are not exposed to conventional language (e.g., deaf children growing up among hearing adults without access to sign language) have been known to invent spontaneous gesture systems to communicate. Crucially, the properties of these systems seem to be similar to those of early speech (children begin with simple gestures, then produce two-gesture combinations and later more complex "sentences"). Similarly, children exposed to improvised and irregular language-like systems (*pidgins*) constructed by members of different language communities who find themselves living in the same environment transform these imperfect systems, as they learn them, into rule-governed languages (*creoles*). Finally, children whose parents are non-native speakers of either a spoken or a signed language typically regularize the incorrect linguistic forms they are exposed to. In all these cases, children go beyond the information they encounter in the input—in a sense, they create, rather than simply acquire, language.

Further support for the conclusion that learners contribute substantially to language growth comes from studying how changes in a learner's mental preparedness affect language acquisition. Evidence from abandoned and neglected children suggests that the age at which these children were found had a profound effect on whether their language ability could be restored. Experimental data from sign language show that late exposure to a first (signed) language has deep negative effects on learning (similar effects of late exposure hold for second language acquisition). Such critical period

effects demonstrate that the maturational state of the learner's brain is crucial for the attainment of a language system.

Several questions remain open about the mechanisms underlying language learning. One issue is whether specific aspects of language acquisition should be attributed to language-specific versus general-purpose learning mechanisms. Another issue is whether children's native language can affect the way they think, and whether language is necessary or helpful for the development of human concepts.

Anna Papafragou

See also Aphasias; Audition: Cognitive Influences; Context Effects in Perception; Speech Perception; Top-Down and Bottom-Up Processing; Word Recognition

Further Readings

- Baker, M. (2001). *The atoms of language*. Oxford, UK: Oxford University Press.
- Bloom, P. (Ed.). (1993). *Language acquisition: Core readings*. Cambridge: MIT Press.
- Chomsky, N. (1986). *Knowledge of language: Its nature, origin, and use*. New York: Praeger.
- Clifton, C., Frazier, L., & Rayner, K. (Eds.). (1994). *Perspectives in sentence processing*. Hillsdale, NJ: Lawrence Erlbaum.
- Gleitman, L., & Liberman, M. (Eds.). (1995). *An invitation to cognitive science: Vol. 1. Language*. Cambridge: MIT Press.
- Pinker, S. (1995). *The language instinct*. London: Penguin Books.
- Trueswell, J., & Tanenhaus, M. (Eds.). (2006). *Approaches to studying world-situated language use*. Cambridge: MIT Press.

LATERAL INHIBITION

Lateral inhibition, is a decrease in response in neurons that occurs when neighboring neurons become activated. For example, in Figure 1(a), a network of 10 excitatory neurons receiving information from visual space (such as neurons in the retina or later levels of the visual system) is intermingled with 9 inhibitory neurons. Activity in any one of the excitatory neurons can inhibit its neighbors indirectly by activating the inhibitory

neurons that then inhibit their neighbors. When a stimulus (such as a bar of light or any other stimulus) excites a number of neurons in the network (in this case neurons 4e, 5e, 6e, and 7e), the effect of inhibition is to suppress the neurons just outside the edge of the bar (3e and 8e) because those neurons are inhibited but not excited. Further, because the neurons just inside the edges of the bar (4e and 7e) are excited by light and only inhibited by one neighbor, they are especially active. This leads to perceptual contrast enhancement at borders. Further research showed that lateral inhibition also applied to overlapping stimuli, and that its strength fell off with distance between the interacting stimuli.

Haldan Keffer Hartline won the Nobel Prize in 1967 for discovering lateral inhibition and its neural correlates. The first inhibitory circuit in the nervous system was found in the horseshoe crab (*Limulus polyphemus*). Here, an activated photoreceptor was inhibited when a laterally adjacent (or nearby) photoreceptor was also activated. Lateral inhibitory circuits are currently known to be ubiquitous to all sensory areas of the brain, and they play an important role in many sensory, cognitive, motor, affective, and limbic processes. The most common mechanism by which neurons suppress their neighbors is through the inhibitory neurotransmitter gamma-aminobutyric acid (GABA).

Hartline and his collaborator, Floyd Ratliff, went on to characterize the three components of a laterally inhibitory circuit: (1) Excitatory input and output—information input arrives at a given sensory area of the brain in the form of excitatory neural responses. Information output is sent to the next area(s) in the hierarchy also in the form of excitatory neural responses; (2) Self-inhibition—neurons that laterally inhibit their neighbors also inhibit themselves; (3) Lateral inhibition occurs as a function of excitatory activation—thus inhibition follows excitation in time.

The Role of Lateral Inhibition Through Time

In addition to its effects across space, lateral inhibition also leads to temporal effects over time. Let us now examine two neurons embedded within a lateral inhibitory network as a function of time (Figure 1b): one excitatory neuron (at times 1e