MISSION IMPOSSIBLE?
cracking the speech code

By Remen E. Okoruwa

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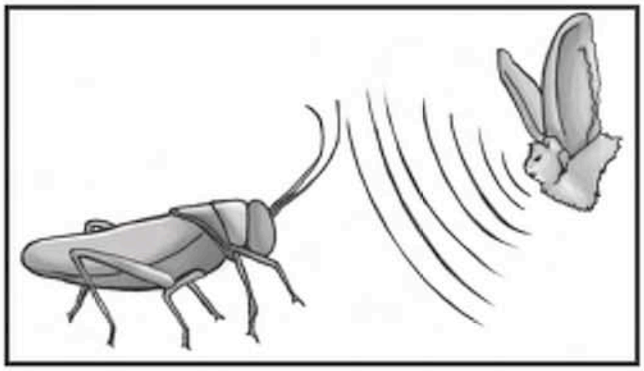
The acquisition of language has been the subject of fruitful investigation for much of the past thirty years as scientists have raced to discover the secret behind learning to speak. It seems an almost magical process as parents with no formal linguistic training can teach grammar and vocabulary to infants who effortlessly learn these structures with a speed exceeding those of any adult learner. Within the span of only twelve months, a child learns the structures of its native language and can begin producing words (1), all the while remaining illiterate and lacking any formal instruction. Indeed, it appears that ability to acquire language is as much a function of an inherent language acquisition system hardwired into children's brains as it is an indication of the time spent by parents reading and speaking to their children. The mechanisms underlying this process continue to fascinate researchers who probe the secrets of the mind looking for the how's and why's of language acquisition.

Background

It is hardly surprising that many theories have been posited attempting to explain how children acquire language so easily. In 1957, B.F. Skinner suggested that language acquisition is merely a matter of operant conditioning with external rewards or punishments shaping the child's learning pattern(2). This view failed to take into account the overwhelming amount of evidence which currently suggests that there are definite physiological mechanisms that enable the young brain to acquire



ABOVE: Bat using sonar echolocation, which signals crickets to flee.

credit: Frances Yun, HSR Design Board

language with tremendous proficiency. Noam Chomsky, in response to Skinner's theory, put forth his own views on language acquisition. Chomsky asserted that humans are biologically endowed with an innate "language faculty." Each child, he argues, is born with an instinct for language or universal grammar. He believes that there are a finite number of parameters or settings that define the rules of grammar and phonetics, and when children are learning language, they are establishing the parameters of the their given language.

Chomsky's selectivist approach to language acquisition now predominates as the generally accepted theory in the field, although the details of exactly how the selection mechanism operates remains highly disputed. Peter Eimas has suggested that infants possess inherent "phonetic feature detectors" evolved for speech, neural mechanisms that respond to the phonetic contrasts utilized by languages of the world(2). More recently, Patricia Kuhl has suggested an alternate mechanism for language acquisition detailed in her Native Language Magnet Theory. Kuhl posits that there is no inborn phenomic distinction, but instead that infants have an innate ability to extract the salient structural properties of sound patterns via statistical analysis(2).

Categorical Perception

The idea of categorical perception lies at the heart of all theories of language acquisition. Categorical perception in general refers to the compression of items within a category. Within the realm of language, categorical perception refers to how a range of audio inputs are interpreted invariably interpreted as a single sound, or phoneme. For example, English-speakers have an established distinction between the /p/ and /b/ sounds, and yet, the /p/ and /b/ sounds lie on a continuous acoustic spectrum. Somehow, English-speakers learn that one side of this spectrum sounds like /p/, and that after a certain arbitrary point on the voice-onset spectrum, that sound is perceived as /b/. There is in fact no universality in the categories established by language. While English speakers have no difficulty distinguishing between the /l/ and /r/ sounds, Japanese speakers raised with only Japanese language input cannot distinguish between those two consonants(1). Understandably, native Japanese speakers have trouble distinguishing between English words using the /l/ and /r/ sounds as the distinction between the phonemes is lost. Tonality and duration are other criteria which serve to differentiate phonemic categorizations used by different languages. Mandarin utilizes a tonal system in which identical vowel-consonant combinations spoken in different tones create words with different meanings. In Finnish and Japanese, the duration of a vowel is a critical component in determining phonemes.

Categorical perception, while present in other faculties, does not carry the same level of distinctness as it does in auditory discrimination. For example, one can visually assign redness or blueness to an object, but this is perceived on a spectrum. Consequently, at the interface of these two colors, there is no discernible separation between red and blue, but instead what is considered purple. Phonemes maintain distinction as they approach boundaries of similarity, and at the threshold one phoneme or the other is perceived. There is no middle ground. In addition, categorical perception is not limited to only humans. Crickets are known to display a sensitivity to mating sounds, which are 4-5 kHz in frequency. Bat sonar pings occur at 25-80 kHz, and this sound frequency usually signals crickets to flee. For crickets, Phonemic units

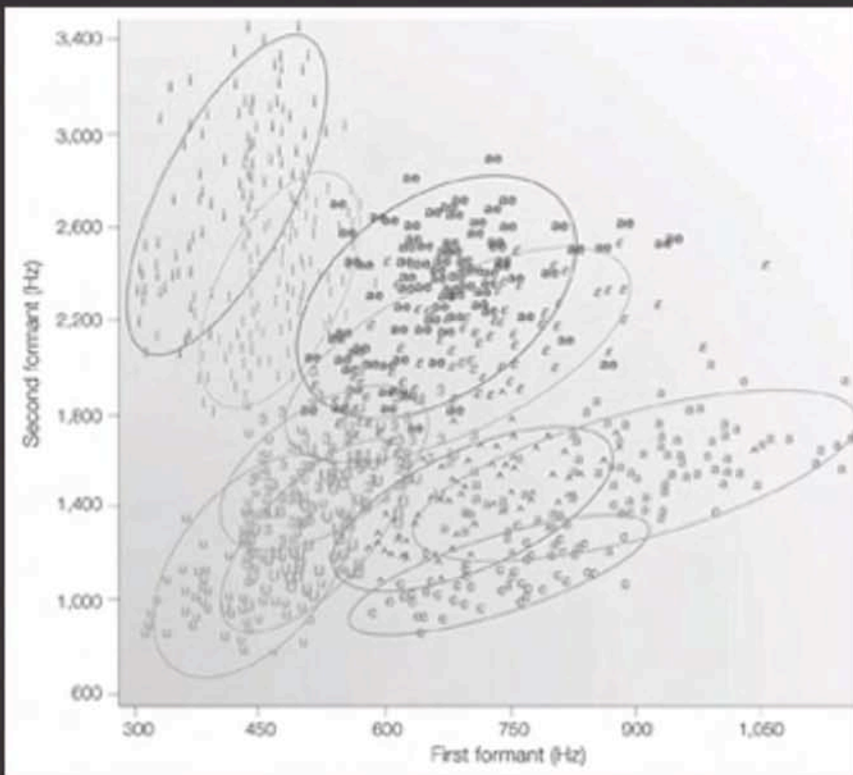


Figure 1. There are fininte sets of phonemic units; each contain a large diversity of acoustically distinct utterances.

credit: Patricia K. Kuhl - Nature Reviews Neuroscience 5, 831-843 (November 2004)

a boundary exists in the range of 13-16 kHz, and anything above this boundary switches the attraction response to the aversion response. But the habituation of crickets to a 20 kHz frequency removes this distinction altogether, and frequencies above 20 kHz no longer elicit avoidance. After the habituation, only sounds at the 16 kHz frequency elicit the aversion response, suggesting that the categorical distinction is retained at the boundaries(3).

If categorical perception is displayed in other species for purposes aside from language, then it is no stretch to surmise that the necessary mechanism may have been co-opted by evolution, and used in conjunction with other necessary faculties to produce the speech and language ability that humans now possess today. This fits in nicely with the Faculty of Language Broad proposed by Hauser, Chomsky and Fitch (4), which proposes that the basic machinery of language, including the sensory-motor and conceptual-intentional systems are not necessarily uniquely human.

Neural Physiology and Learning Strategies

There is now even neurophysiological evidence associated with learning a language. Although infants can initially discriminate between the phonemes of all possible languages, by around 11 months they display a decreased ability to discriminate between foreign-language consonants along with an increased recognition of native language consonants (1). There is now strong evidence that his phenomenon is the result of mappings of pertinent phonemes forming in the auditory cortex of the infant brain, a process referred to as the Native Language Neural Commitment (NLNC). In adults, evidence for this has been found for this in adults via magnetoencephalography magnetoencephalography (MEG) experiments, which show that subjects exposed to a foreign language activated more parts of the brain for a larger time than when exposed to their own native language. This suggests an inefficiency in processing the foreign language data, which may arise from the "neural commitment" in the brain to one's own native language(5).

During the critical first twelve months of an infant's life, the nascent brain is mapping the phonemic distinctions of language as auditory input is provided to the child. Research has indicated that the analysis of statistical patterns in language may be a critical tool in this process. In one study, infants were shown to prefer novel sound patterns to those which they had been already exposed to; it was even shown that this preference arose out of the probabilities inherent in the sound patterns as opposed to frequency of phoneme occurrence(1). Children also learn to recognize prosodic cues such as pitch, tempo, tone, and stress imposed on phonemes, words, and phrases. For instance, 90% of multi-syllabic conversational English words use a trochaic stress pattern (stressed-unstressed), while Polish utilizes the iambic (unstressed-stressed) pattern. Consequently, an English-exposed baby is likely to segment the phrase "again you" (unstressed-stressed-unstressed) by grouping "gain-you" as a single word phrase.

Raising an infant in a bilingual environment presents the developing brain with a novel challenge as it has to map two distinct statistical and prosodic patterns onto the brain. Nevertheless, the lack of fixity present in the nascent mind allows for the two languages ultimately to be acquired with ease. The neurological foundations of language also serve to elucidate why learning a

The importance of social interaction

Figure 2. When the sound waves of a television, loudspeaker, and human were projected at infants, they learned best when interacting with a human.

language in adulthood after the critical period for language acquisition is so difficult. The brain is already wired a specific way.

Social Aspects of Language Acquisition

When it comes to teaching language, the medium is nearly as important as the content. A study revealed that when two groups of nine-month old American infants were exposed to Mandarin, either via a televised recording or from a real life speaker, phonetic recognition only occurred in the live exposure group. Further tests demonstrated the same result when the speaker's voice was played over a loudspeaker(1). Learning and social interaction have an integral relationship for young infants, most likely an evolutionarily-derived one. For instance, young zebra finches must visually interact with a live tutor before they can create songs, and the inherent desire of a conspecific (belonging to same species) song can be overridden if they are fed by a Bengalese finch foster father, even when other zebra finches can be heard nearby. Similarly, white crown sparrows will reject songs of foreign birds played by audiotape yet mimic them if presented by a live tutor (6).

Conclusion

Finding the secrets of language acquisition has proven to be a monumental task, butt the progress made already is significant. Research into the evolutionary bases for the faculty of language in humans provides a glimpse of the pathway humanity followed on its way to speech, yet so many pieces of the puzzle are still missing. Understanding the role of categorical perception in the process remains a subject of inquiry, and many of the other assimilated faculties have yet to be illuminated. Further research into the nature of the understanding the mechanics of how children acquire language are also critical for the future of technology and artificial intelligence. As our knowledge of the mechanisms of the mind increases, the day when machines can imitate the ability comes closer and closer. H

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