Getting the beat

Probably the most important characteristic that sets us apart from everyone else in our common, billion-year-old, highly branched evolutionary tree is language (Pinker 1994). Language allows us to communicate across the boundaries of space and time and, according to some, is also the source of what is termed 'consciousness'. The problem of language acquisition was not fully appreciated till the Chomskyan revolution in the 1950s. Chomsky pointed out that language learning was a problem because of (i) the impoverished nature of linguistic inputs to a child and (ii) the powerful, almost infinite creative power of the language learnt. Given the ability of learners to generate previously unheard sentences, all of them satisfying the non-trivial constraint of being grammatically correct, Chomsky pointed out that language acquisition cannot be explained in terms of the simpler description of the behaviourists, i.e., in terms of stimulus–response routines (Chomsky 1980).

Chomsky constructed (and continues to do so) an elaborate and compelling theory of language. An important part of the theory, what came to be called Universal Grammar (meaning that in a deep sense, all languages have the same grammatical structure), is its *innateness*. In effect, Chomsky said that Universal Grammar was written in our genes. By saying that language is innate, Chomskyans do not mean that we "know" the words and the grammar from birth. What they mean – and the exact meaning has been evolving ever since the theory was first propounded – is that there exists in the minds of babies a certain Language Module, which is some sort of a genetically-based neural blueprint or module waiting to encounter a real language in the world. The 'blueprint' is specifically designed to assimilate one or more languages and provide the means for using it. Today language learning is looked upon as an example of a broader idea, namely, that much of cognition is based on analogous modules, but that is another story. As an aside, it might appear that a genetically-based language module implies that language capability must have evolved by natural selection. But on this point Chomsky remains skeptical (see Pinker 1994).

How might the language module inside a baby figure out the grammar and the words? One would think that learning just the words should not be too difficult a task. Perhaps it could even be automated. All that would be required is to record someone's voice and run the acquired speech waveform through the appropriate algorithms to discover all the words embedded in the waveform. (A speech waveform, like any sound waveform, looks like a squiggly line going along a time axis, and represents the amplitude of the vibration of your eardrum at every instant in time over the duration of the sound.) Only, it turns out that this 'segmentation task' is, computationally, a fiendishly difficult task. When we speak, we run words together in such a manner that there is no efficient algorithm today that can reliably pick out word-like entities from a speech waveform when the words are unknown. And, unless you believe that somehow the words are hardwired into a baby's brain, this is exactly the task that the language module seems to perform, seemingly effortlessly. Over the years, several laboratories have shown that babies are exquisitely sensitive to several statistical properties of the sounds they hear and these features could aid the child in solving the segmentation task.

But our speech is not just words, it is also the way we speak them. We stress some portions and not others, our tone rises sometimes and sometimes it falls, some parts are said quickly while others are slowed down. These rhythmic and intonational properties are referred to as the *prosody* of the language, and it is similar to the beat or the tempo in music. Prosody is very different in different languages. In Indian languages words lend to be unstressed. In Italian most words receive the stress on the penultimate syllable; in French it is the ultimate syllable that receives the stress. Babies are sensitive to these cues, and could use these in addition to the statistical cues to segment the speech streams that assail them. Babies have been shown to be able to discriminate the rhythm of their own language (and languages with similar rhythms) by the time they are four days old. Their response is not merely to the statistical nature of the sounds produced; they do not show this sensitivity when speech to which they respond best is run backwards.

Those who believe that the language module is something unique to humans would say that these sensitivities should be specific to humans. But researchers have shown the need for caution by demonstrating that certain simple properties of the way we perceive speech such as the categorical perception of phonemes, that were once thought to be exclusively human, are also shared by other

animals like Chinchillas and even by quail and starlings (though these studies have been dogged with methodological and philosophical controversy). Phonemes are the basic sounds used in a language, like /pa/ and /ba/. English, for example, has about 44 phonemes. Categorical perception is when one automatically tends to ignore differences between acoustically different instances of the same phoneme. But could it also be the case for more complex stimuli like the overall rhythmic pattern in a segment of speech that other animals too share this analysis?

The groups of Jacques Mehler, studying language in babies (and adults) at CNRS, Paris and Marc Hauser, working on primate cognition at Harvard University, ran experiments in parallel on human newborns and cotton-top tamarin monkeys to address this question (Ramus *et al* 2000; Werker and Vouloumanos 2000). The experiment consisted of sentences in Dutch and Japanese, two languages with very different prosodic structures. The experiments used a paradigm, referred to as habituation-dishabituation, which allows one to see if two stimuli are perceived to be similar or different. It works like this: you show a baby (or a monkey) the first stimulus, and the baby responds in a measurable way because it senses something novel in its environment. After a few repetitions of stimulus #1, the baby gets tired (habituated) and stops responding. Now, if the experimenter switches to stimulus #2, and if the baby perceives it as being different, it will once again start responding; it would have become dishabituated. On the other hand, if the experimenter were to switch to stimulus of category #1, or if the baby did not perceive any difference between stimulus No. 1 and stimulus No. 2, it would continue being bored and not respond to the stimuli.

The basic result from this experiment was that both the babies as well as the monkeys were able to distinguish the Dutch sentences from the Japanese ones when the speech segments had been corrected to differ only in their prosody. Furthermore, this discrimination was evident only when the speech segments were played forwards; when they were played backwards, the monkeys as well as the babies failed to discriminate the two. Importantly, this is among the few reports in which the animals were not extensively pretrained. In fact the experiment relied on nothing more than the curiosity of the monkeys. This should be contrasted with, the experiments with quail. Several thousands of trials are required to get the quail to reliably discriminate between two phonemes (like /pa/ and /ba/).

But why did the workers choose to investigate prosody? As noted before, prosody can be useful in segmenting the speech stream. In addition, preliminary research seems to indicate that prosodic features in the speech might be related to the nature of the underlying grammar itself. If this were to be true, than an early cue like prosody might already be setting switches in the baby's language organ, telling it what grammatical forms it should expect, and which to reject. In sum, these experiments give us clear insight into the supposed uniqueness of the human 'language module'. As the authors note, the precise nature and extent of the language module is mainly an empirical matter. One can now begin to investigate the extent to which the language module is truly a uniquely human entity, and how much of it is a constraint imposed by our evolutionary history.

References

Chomsky N 1980 *Rules and representations* (New York: Columbia Univ. Press)

Pinker S 1994 *The language instinct* (New York: William-Morrow)

Ramus F, Hauser M D, Miller C, Morris D and Mehler J 2000 Language discrimination by human newborns and by cotton-top tamarin monkeys; *Science* **288** 349–351

Werker J F and Vouloumanos A 2000 Who's got rhythm?; *Science* **288** 280–281

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