



PERSPECTIVES: LANGUAGE

Who's Got Rhythm?

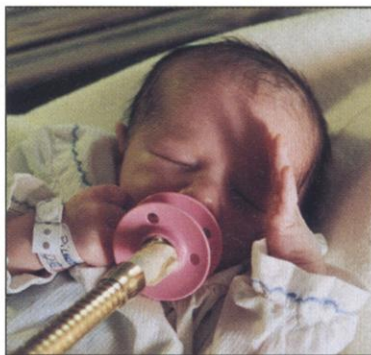
Janet F. Werker and Athena Vouloumanos

Language is a brilliant invention of the mind. Normal language acquisition in humans is characterized by spectacularly quick, effortless, uninstructed learning, and leads to universal linguistic competence. Remarkably, no other species has evolved as sophisticated a system of combinatorial symbolic communication. Just as echolocation allows bats and dolphins to orient themselves and locate others, and honeybees dance to lead their hive mates to pollen, language seems to be the quintessential human trait, our endowment from evolution, innate and instinctive.

But is linguistic input a privileged stimulus for humans, arising from distinct evolutionary specializations? To make such a claim, at least two fundamental premises must be met. First, human neonates, who have not yet had extensive exposure to language, should show an advantage in processing linguistic sounds. Second, this specialized linguistic processing should be unique to humans. On page 349 of this issue, Ramus *et al.* (1) tackle the second premise by contrasting the perception of the rhythmic properties of speech in newborn human infants with that in cotton-top tamarin monkeys (see the figure).

Decades of research have demonstrated that many other species, from the chinchilla to the budgerigar to the Japanese quail, perceive the phonetic contrast that distinguishes, for example, /ba/ from /pa/ in human speech (2). Although interesting, these earlier insights were limited not only because many interpretations can account for the similarities in cross-species performance, but also because language relies on more than the discrimination of isolated minimal phonetic pairs. Ramus and his colleagues present a fresh perspective by examining the perception of continuous speech, and its constituent rhythm, as it ex-

ists in natural language. Rhythm is paramount for distinguishing one family of languages from another (3), and, among other functions, helps the listener to decide whether the speaker belongs to the same social group. Moreover, rhythmicity provides critical cues for parsing utterances into constituent elements, such as words, phrases,



Rhythm and blues. Analogous tests for a novelty response were used to determine discrimination of two rhythmically distinct languages (Dutch and Japanese played forward and backward) in cotton-top tamarin monkeys and human newborns. Cotton-top tamarin monkeys show a novelty response by turning their head toward a new stimulus (right). Human newborns show a novelty response by an increased number of high-amplitude sucks on a pacifier (left). In the habituation procedure, the listeners were repeatedly presented with a stimulus (for example, one language played forward) until they showed, through a criterial decrement in response, that they no longer found the stimulus interesting. They were then presented with a new stimulus (for example, the second language played forward). If they detected a change from the familiar to the new stimulus, they showed renewed interest (a novelty response).

and clauses, which form the building blocks of human grammar.

Ramus and co-workers conducted comparative studies to test the uniqueness of human linguistic processing. Using analogous procedures to determine responses to the rhythmic structure of human languages, they compared the ability of a nonhuman primate species and human infants to discriminate Dutch and Japanese played forward and backward (see the figure). The major finding from their research is that adult tamarins, like human infants, can discriminate continuous speech from two rhythmically distinct languages, but only if the speech is played forward. When the speech is played backward, rendering it nonlinguistic, both humans and tamarins fail to distinguish between the two languages.

Their results point to similarities between the tamarin and human perceptual systems, and force us to consider that this type of speech processing—even though immediately apparent in human neonates—might not be unique to humans. A conservative solution is to suggest that tamarins perform like humans because the rhythm of human speech is of functional significance to both species. Because nonhuman primates share many mechanisms of breath control with humans, similar rhythmic elements could characterize their own vocalizations (4). But surely humans do not have exactly the same neurobiological and perceptual makeup as tamarins. Tamarins never learn to use human language to communicate, no matter how much exposure they are given. So, we must look for differences elsewhere.

First, it is possible that although humans and tamarins differentiate rhythmically distinct languages behaviorally, this discrimination might be implemented in different ways. These adult tamarins have had a lifetime of exposure to human language. Human infants, although lacking the same amount of exposure, heard rhythmic aspects of speech while in the womb, a period in development during which exposure may have a more profound impact on the organization of the brain than does learning after birth. If so, tamarins may be using laboriously constructed processing strategies resulting from prolonged exposure to human speech, whereas humans

might be relying on much faster, perhaps preorganized, neural mechanisms.

How would different processing mechanisms be manifest? One possibility is that different brain areas might mediate the two processes. Although nonhuman primates rely on subcortical structures in the perception of their own vocalizations more than humans do, they possess cortical regions analogous to Wernicke's and Broca's areas (regions known to process language in humans) (4). But what if convergent evolution had driven different brain areas to take on similar processing tasks? Or worse, suppose the same brain area evolved to perform different operations, so that what appeared the same across species in fact involved quite distinct processes. Clearly, future studies must address these questions.

The authors are in the Department of Psychology, University of British Columbia, 2136 West Mall, Vancouver, B.C. V6T 1Z4, Canada. E-mail: jwerker@cortex.psych.ubc.ca, athenavou@interchange.ubc.ca

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There is yet another possibility. Our shared mammalian evolutionary history may have provided tamarins with perceptual systems that make all the same discriminations that humans have for speech perception. It would then appear that the perception of speech by tamarins might be analogous to human speech perception. But is it really? Perhaps the difference lies at a later point in perceptual processing, one requiring more complex integration of these discriminations. What might then be unique to humans is not the ability to make appropriate auditory discriminations, but rather the ability to coordinate these auditory discriminations in the service of language acquisition. By 6 to 7 months of age, human infants can use overall rhythm to "predict" clause and phrase boundaries (5), and by the age of 9 months, human in-

fants not only discriminate rhythmic structure and syllable sequence, but also coordinate these two sources of information to pull out "word-like" multisyllabic rhythmic units (6).

The integrative tasks that infants perform are arguably crucial for language acquisition. Do nonhuman primates coordinate the output of their auditory discriminations in the same way as humans do? And are they, like human infants, selective in just which kinds of information they combine? If they are not, then the defining characteristic of human language processing would lie not only in the types of auditory discrimination that are made, or where in the brain these discriminations occur, but also in the integration of auditory discrimination and the brain areas performing these operations.

In revealing our sometimes naïve con-

ceptions of what makes language special, Ramus and his colleagues allow us to revisit past work and redirect the inquiry. It will be essential to explore not only what is similar between human neonates and other species, but also to investigate just what allows the human mind to negotiate its own complex invention that is language.

References

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PERSPECTIVES: ASTRONOMY

An Infrared Look Behind Stars

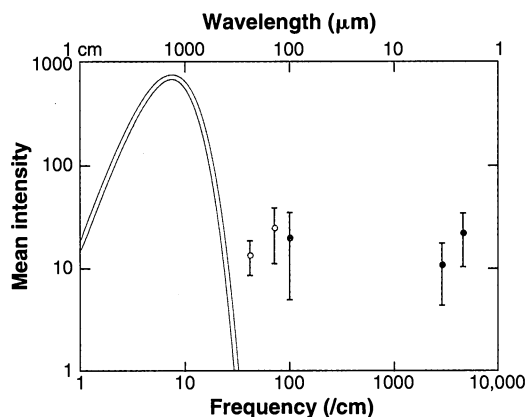
Craig J. Hogan

A quick glance at the night sky reveals that the sky is mostly dark, a profound fact that in itself reveals much about the history of the universe and of the stars within it. Of course, it is not perfectly dark: It glows from Earth's atmosphere and from the zodiacal light of sunlight reflected from dust between the planets, and is peppered with stars because we are viewing the universe from inside the disk of a fairly large galaxy. If we could get outside our Galaxy, the Milky Way, the sky would look much darker but would still glow faintly because the universe is full of galaxies.

Because most of the volume of the universe is far away, that light comes mostly from very distant galaxies. Two forthcoming papers (1, 2) demonstrate that it is now possible to subtract the foreground emission and peer between the stars of our Galaxy to estimate the glow of the universe at large, which is dominated by the time when the universe formed most of its stars. This has enabled the total global conversion of matter into stars and starlight to be directly measured, amounting to a complete audit of the overall energy budget of starlight in the universe.

Most of the light in the universe was produced in the Big Bang, the inflationary event that started the cosmic expansion.

This light appears today as background radiation coming almost perfectly evenly from all directions on the sky. It has been redshifted by the cosmic expansion and now has the spectrum of a simple Planck blackbody at a cool 2.728 ± 0.002 K, with most of the energy at wavelengths of 0.8 to 3 μm . Light emitted since the Big Bang has come from various sources, such as stars, quasars, and clouds of hot gas. The sum of



Mean energy densities of light in the universe. At long wavelengths (left), the mean energy is dominated by the microwave background (solid curve). Extragalactic dust emission dominates from 100 to 300 μm (blue and green points with error bars) (2, 5). New measurements show direct, redshifted starlight that dominates at 2 to 3 μm (red points with error bars) (1, 2). The near and far infrared backgrounds are comparable to each other (an indication that roughly half of starlight has been absorbed and reradiated by grains) and together contain about 30 times less total energy than the microwave background. Mean intensity in nW/m^2 . [Adapted from (2)]

all of these sources, even those too faint to observe individually, blends to form an extra, nonprimordial background. Cosmic backgrounds at various wavelengths carry information about the total light emission history of the universe in all forms.

Anyone can see that a lot of starlight is emitted at visible wavelengths. The visible-light background is now known to be dominated by galaxies that can be directly imaged in deep surveys such as the Hubble Deep Field; the sum of visible light from invisibly faint galaxies is less than that already accounted for in visible ones. However, most starlight is emitted in the infrared, and in the expanding universe the light gets further shifted to the red by the cosmic expansion. If light is absorbed by cosmic dust, it gets reemitted at even longer wavelengths, corresponding to the cool temperature of the dust grains. Therefore, a full census of starlight (as well as quasar light, which can also be absorbed by dust) requires a measurement of cosmic background far into the infrared.

The Cosmic Background Explorer (COBE) satellite has provided critical data sets for these measurements. The Far Infrared Absolute Spectrophotometer (FIRAS) instrument, which made the spectacularly precise measurement (a few parts in ten thousand!) of the blackbody character of the primordial cosmic spectrum at 0.8 to 3 μm , also detected small deviations from a blackbody at wavelengths shorter than 0.8 μm , which become dominant below about 0.4 μm . The deviations are

The author is in the Departments of Astronomy and Physics, University of Washington, Post Office Box 351580, Seattle, WA 98195, USA. E-mail: hogan@astro.washington.edu