NEUROSCIENCE MEETING

Brain Researchers Speak a Common Language

SAN DIEGO—This year's 25th annual meeting of the Society for Neuroscience was the largest ever, as nearly 23,000 neuroscientists crowded into the convention center here to sample more than 12,000 talks and poster presentations. Just one of the countless areas covered at this year's meeting was how the brain processes language. Imaging studies of the human brain, as well as studies of songbirds, whose learning of song has some parallels with our learning of language, are shedding light on this uniquely human trait.

Vive la Différence

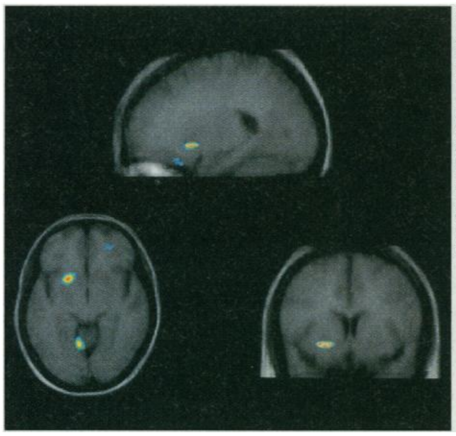
Anyone who has tried to master a second language in adult life knows the mental effort it takes. Struggling adult learners may envy those who became fluent in a second language while they were still young. But at the San Diego meeting, neuropsychologist Brenda Milner of McGill University in Montreal reported evidence suggesting that even people who have been fluent speakers of a second language since childhood still use a little extra brain power to speak their non-native tongue. The result has piqued the interest of neuroscientists because the apparent site of that extra brain power is a deep brain region called the putamen, an area not previously thought to play a special role in the memory of learned language.

Milner and postdoc Denise Klein made the discovery while studying how language tasks activate various regions of the brain. Because they work in the predominantly French-speaking province of Quebec, it seemed natural to add an extra twist to their experimental design and compare the brain activation patterns generated in bilingual individuals speaking French with those generated while they were speaking English.

As subjects for their study, Klein and Milner chose native English speakers who had learned French when they were about 7 years old and spoke both languages fluently and daily. The researchers imaged the subjects' brains with positron emission tomography, which measures cerebral blood flow (an indicator of brain activation), while they were doing one of several spoken tasks that included repeating a French or English word or speaking its synonym in the same language, and translating words from English to French and vice versa.

When the researchers compared the brain activation patterns of subjects performing the tasks in English versus French, they found equivalent activation in all brain areas, with one striking exception. "Whenever the [spoken] response was in French, we saw the left putamen lighting up," says Milner. The putamen was silent, however, when the subjects answered in their native English. The fact that the putamen was activated when the subjects were speaking French suggests, Milner says, that even though these people are fluent, "there is some sort of extra control of articulation" required for them to speak their second language.

This was a bit of a surprise, because the putamen had not previously been linked to language learning. It is part of the basal ganglia, a collection of brain structures sitting underneath the cortex in the front of the brain, whose main role was thought to be the production of rote movements.


BRENDA MILNER/MCGILL UNIVERSITY

Non-native. In these three brain views, the putamen is activated differentially when a native English speaker speaks French.

Still, Milner and Klein's result does fit with recent work suggesting that the brain area may have a role in the learning and memory of tasks involving movement, says Ann Graybiel, a neurobiologist who studies the basal ganglia at the Massachusetts Institute of Technology: "If we interpret [Milner and Klein's result] in a straightforward way, then it seems that something you have had to put your mind to, to learn, has a special trace in the basal ganglia, reflective of a role of basal ganglia in learning and memory." The finding is also consistent with other evidence that learning and memory are distributed in many brain regions rather than being isolated in specific structures.

Milner plans to follow up the finding, first of all by making sure that it is not specific to English speakers who have learned French. She intends to do the reverse experiment with native French speakers who learned English at an early age and also hopes to check the effects on the brain of learning other languages that are even more different from English, such as Chinese. If those findings support the first results, then late language learners can find solace in knowing that even facile multilinguists who learned their second language at an early age need an extra boost from their putamens.

Baby Sparrows Thrive on Word Salad

To understand the human brain, neuroscientists often turn to the brains of mammals, such as rats or monkeys. Language, however, is a uniquely human trait, into which rats or monkeys provide little insight. But our more distant relatives, the songbirds, do have something akin to language: For their mating songs, they learn a complex vocabulary of whistles, buzzes, and trills. Some researchers believe the way their brains do this may provide insights into how our brains learn language. Those researchers will take heart from new results presented in San Diego by Carol Whaling, a postdoc with behavioral neurobiologist Peter Marler at the University of California (UC), Davis, and neurophysiologists Allison Doupe and Michele Solis of UC San Francisco.

The group found that baby birds distinguish the song of their species by responding to individual sounds making up the song. That process seems to parallel the one seen in human infants, who recognize individual vowels and consonants common in their language before they learn words, phrases, and sentences. And it's reflected in a change in the selectivity of the birds' neurons—a change that suggests parallels with how human infants learn language.

Until recently, most bird-song research has focused on exploring the neuronal changes that occur as adolescent birds learn to sing. That work has shown that, while the learning is going on, neurons in the brain's song-production center, known as HVC, show increasingly selective responses to song. Early in learning, individual neurons respond to multisyllabic phrases of song from any bird of the same species, even if these phrases are presented out of order. Later the neurons become more specific, requiring the song to be in the right order, ignoring most species members and responding best to the bird's own song or that of its tutor. Finally the HVC neurons respond only to the bird's own song.

Whaling and her colleagues, however, decided to take a close look at the HVC neurons in naive baby birds, to see how much selectivity these neurons start out with. Because baby birds have an innate ability to recognize their own species' song, some researchers suspected that the neurons might be innately programmed to recognize whole multisyllabic sequences of that song.

The new work shows that isn't quite the case. The team found that both baby birds and their neurons start with a more general kind of selectivity for the individual words or syllables of which that song is made. This, says Doupe, is reminiscent of what University of Washington psycholinguist Patricia Kuhl has shown to occur in human babies, who recognize the vowel and consonant sounds of their language before they learn words.

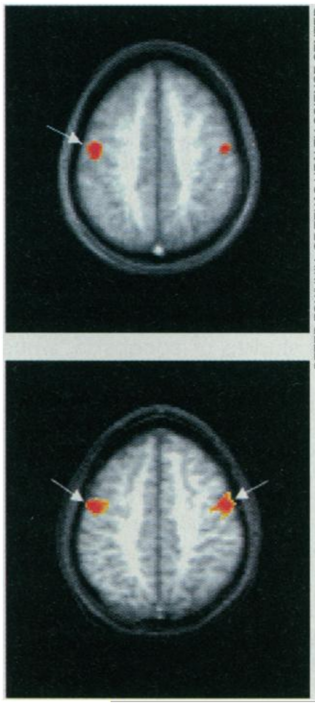
The team came to this conclusion by first playing parts of white crowned sparrow song, as well as parts of the songs of other sparrow species, to baby white crowned sparrows that had never before heard song. As previously shown in Marler's lab, baby birds peep when they hear their species' song, and the researchers found that the baby sparrows responded not just to the complete song of their species, but to individual whistles, buzzes, and trills, played forward or backward or jumbled together in random ways.

When the group recorded the activity of the birds' HVC neurons, they found that they parallel the birds' behavior, responding to syllables rather than multisyllabic phrases. Some neurons specialized in recognizing whistles; others liked buzzes or trills, either played forward or backward. "These neurons are all tuned to individual features of a song," says Whaling.

Now, says UCSF's Doupe, "we can go in and find what's changing neurally" as a bird learns to sing and its HVC neurons go "from initially responding to all species syllables backward and forward, later to syllables, but only forward, and finally only to the right syllables in the right order." That's an exciting prospect, says bird-song researcher Daniel Margoliash of the University of Chicago: "It allows us in very quantitative terms to explore this issue of innate versus environmental [learned] influences ... and how it interacts with the [neurological] process that eventually results in the adult song." And it might just shed some light on how language transforms our own brains.

Stuttering Comes Into Focus

To an onlooker, a stutterer struggling to get out a sentence appears to be having trouble with the motor control of his lips and tongue. And in fact that has been what some neurobiologists who study stuttering have suspected. But a new brain imaging study implies that movement control is unlikely to be the whole stuttering story. The results, reported in San Diego, suggest that the origins of stuttering may lie deep in multiple language centers of the brain.



PETER FOX/UNIV. OF TEXAS HEALTH SCIENCE CENTER

Skewed. The motor cortex activation in a stutterer's brain *(bottom)* lacks the left dominance seen in normal controls *(top)*.

Performed by Peter Fox of the University of Texas Health Science Center in San Antonio, Roger Ingham of the University of California, Santa Barbara, and their colleagues, the study doesn't pin down a single cause in the brain; researchers who have linked stuttering to defects in motor control, auditory feedback, and overall language development will all find support in the group's findings. But the work does suggest that brain imaging could eventually bring stuttering into sharper focus, and may even help illuminate which interventions, if any, can reduce stuttering by making stutterers' brains more normal.

The team used positron emission tomography scanning to compare the overall brain activation of 10 normal right-handed men to that of 10 right-handed male stutterers. Each subject was scanned while reading a paragraph aloud on his own, and again while reading aloud in unison with a recording. That condition, called "chorus reading," is known to suppress stuttering, and did so in the stutterer subjects.

The researchers found significant differences between activation levels in the brains of stutterers and normal subjects during solo reading. In normal right-handed men, brain activation was higher on the left side of the brain than on the right in the areas that control the movements necessary for speech, and also in the auditory areas that process incoming language information. That makes sense, as language is normally controlled almost exclusively from the left half of the brain. But the stutterers were far less left-dominant; activation in their brains was shifted toward the right in both the motor and auditory language areas, revealing an inherent difference in the way the two groups process language.

And that difference persisted, even during chorus reading, when the men weren't stuttering, suggesting that it reflects a fundamental difference in brain organization. During chorus reading the differences in the motor areas were less pronounced, but didn't go away. And in the auditory areas the difference between the stutterers and normal subjects was the same during chorus and solo reading: The stutterers' left auditory speech areas were nearly silent, while those of the controls were highly active.

The chorus reading results point to what might be a key flaw in handling auditory information. During chorus reading, the stutterers, like the controls, showed activation of their right auditory cortex in response to the recorded reading, which was piped into their left ears. But the lack of response in the left auditory region suggests, says Fox, that "they're not moving [the information] over to the left hemisphere," where speech-related auditory processing normally occurs.

Taken together, Fox says, the findings support three different theories of stuttering. The exaggerated brain activation in the stutterers' right motor control areas agrees with the idea that stuttering is a motor problem, while the silence of the left auditory language area supports a second theory that stutterers don't get proper auditory feedback when they are speaking. A third theory, that the stuttering arises from the failure of the brain to develop normal left-hemisphere dominance for language, is bolstered by the general shift of language activity away from the left hemisphere in stutterers' brains. And that, says speech pathologist Christy Ludlow, of the National Institute on Deafness and Other Communication Disorders (NIDCD), is the most striking result of all, because it occurs in all of the language areas studied, making the last theory the winner in her view.

Ludlow and her NIDCD colleague Allan Braun have unpublished findings that are similar to Fox and Ingham's. She and Braun found that when stutterers speak, "the left-hemisphere language areas seem to be reduced in activation compared to normals," even if stuttering is suppressed. That, she adds, means "that we can't look on [stuttering] simply as a motor-control disorder, that it has much more to do with the system interface between language and speech."

Will this idea bring new treatments for stuttering? Not directly, says Ludlow. But if stuttering results from a general flaw in language development, that lends support to a new view that speech therapy should begin as soon as a child shows signs of stuttering or other lack of fluency, often as early as age 4. Treating the problem early, when the language system is still malleable, should offer the best chance of actually influencing language development.

–Marcia Barinaga