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On the Border between Perception and Physiology

Your feet hurt and you're talking to a bore. But through the chatter and laughter and tootling jazz, you can make out, from just over there, a pretty good joke being told.

Behold, the Cocktail Party Effect. It's what lets us zero in on one voice in a hubbub and, more generally, what helps us carve the heard world into understandable parts. Handy—even when you're not holding half a canape. And it's only one aspect of hearing and perception being researched by members of the Auditory Research Group.

"This is neat stuff," says Professor H. Steven Colburn. 'The binaural system sort of unfolds space." Using hearing tests similar to those given by audiologists, Dr. Colburn measures a subject's ability to do binaural comparisons—that is, to use the different information each ear has received—then matches what he's found out to mathematical models and research on neuronal responses in animals.

That the research dances on the border between perception and physiology is what initially hooked Professor Colburn. "Can we understand our abilities and limitations by simply understanding how sounds are represented in the peripheral neurons? As you go into the deeper regions of the brain, the physical structures get increasingly complex, [and] the ability to describe what's happening physically gets increasingly difficult. Yet I believe it's all physical, that our sensations and conceptualizations of the world reflect activities of neural populations."

For Assistant Professor Laurel Carney, the main question is clear: "How do we pull information out and process it? My bent is trying to understand how [the normal ear] does it, so we can help the impaired ear.

"Almost everyone starts losing their hearing—just about from birth," continues Professor Carney Yet present remedies, namely hearing aids that amplify difficult frequencies, can't "do the trick. If you know people with hearing aids, just ask them. They'll have trouble in a restaurant where there's a lot of noise in the background. [Amplification] isn't sufficient to restore the ability to use information." In fact, she says, "I think that we know a lot more about encoding and processing sounds in the brain stem than people making hearing aids take advantage of."

The how and why of audition is what sparks the interest of Associate Professor David Mountain, although he works with the underlying biophysics of sound processing. Hearing is fundamentally important "from a survival point of view" because only it and smell can carry warning signals around corners, he points out. "In the forest, if you can identify a sound and its source, you can decide if it's something to worry about—whether you're predator or prey. But what is it that makes the sound of a breaking stick easily identifiable? No two sticks are alike, and no two animals step on these sticks in exactly the same way The average human being doesn't spend much time in the woods, but (can recognize j a breaking stick. Why did Mother Nature choose this system, and how does it work?

David Mountain

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Allyn Hubbard

His model of the inner ear is "actually an adaptation of a circuit used in radar a long time ago. If you look into the cochlea, you see constructions that look practically like the circuit—to me. You have to be an engineer."

"Traditionally," says Professor Mountain, "physiologists have written off a lot of inner ear anatomy—it was too hard to think about." Dr. Mountain, however, measures mechanical properties of the inner ear at the cellular level. "We always joke about wishing we could shrink ourselves down to the size of a single cell, crawl in there, and kind of look around." Forced to settle for a tiny probe, "we go in [to the inner ear of an animal subject], push up against something, wiggle the lip, measure the restoring force, and then push a little harder. Then we move over ten micrometers and push again."

Study is also underway on auto-acoustic emission. The cochlea appears to amplify sound before it's detected and passed on to the brain," explained Dr. Mountain. "[We think] the sound comes in, is transduced from mechanical to electrical energy, and then [back again] when a second process kicks in. It's like positive feedback or a kid on a swing. If you know when to push, you can make the swing go higher and higher.

"Most biological force-production mechanisms, like our muscles, are relatively slow," he continues. "But this happens on a cycle-by-cycle

basis, up to twenty thousand cycles per second in humans. And we're talking about motions which are in the threshold of hearing—on the order of one nanometer: about ten hydrogen atoms end-to-end, like billiard balls. The structures that are doing the sensing and moving in the ear arc actually quite large compared to some of the motions we're able to hear."

Ultimately the research will be applied to developing hearing aids and other devices to counteract hearing loss. "What draws a lot of people to biomedical engineering," says Biomedical Department Chairman Herb Voigt, "is the notion that we're going to be able to help people, to apply the engineering perspective and gain a full understanding of the physiological system. But the more I looked at the auditory system, the more our gross ignorance became blatantly apparent. It was just phenomenal, what we didn't know. Today we're inching ahead, but research takes a long time to conduct. It's very difficult to establish something as a fact."

Professor Voigt records the response of individual neurons to stimuli and studies the neuronal circuitry of the dorsal cochlear nucleus, an area of the brainstem devoted to the processing of auditory information. "It's an enormously complicated neuronal architecture within the nucleus" with many types of cells, "and each is hypothesized to have a different set of response properties.

"Very fine micro-pipctte electrodes are inserted into [animal] brain tissue, either very close to a neuron but not penetrating the membrane, or actually penetrating the individual neuron. We record the action potential"—the impulse with which neurons are thought to transmit information to their targets—"generated by that single neuron." The neuron is marked so "the physiology of the neuron can be associated with the way the neuron responds to acoustic stimuli." Recordings are also made of pairs of neurons firing simultaneously, providing information about functional interaction.

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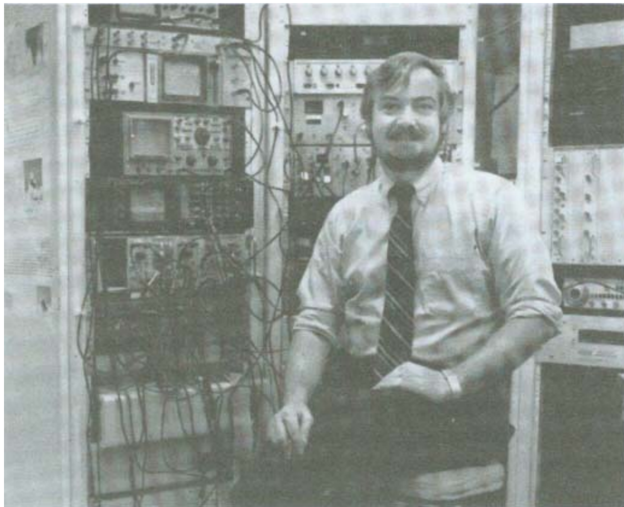

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When that is done, says Dr. Voigt, "we can fold that information into our computer modeling efforts," which aim to simulate the activity of the neurons in the dorsal cochlear nucleus.

Associate Professor Allyn Hubbard approaches the work from a different angle. "I try to carry some of the things about the ear into VLSI," says Dr. Hubbard."[Most of] my modeling [of the auditory system] is with circuit simulators [originally developed] for the communications or the electrical industry. -An offshoot of that is my interest in building chips that will more or less replicate the signal processing we see the ear doing."

Dr. Hubbard has recently developed the first model that can replicate the magnitude phase angle of responses of the inner ear. "It's actually an adaptation of a circuit used in radar a long time ago. If you look into the cochlea, you see constructions that look practically like the circuit," he says, then adds"—to me; you have to be an engineer to look at a circuit and say it looks like something."

The stage for this advance was set at Raytheon, where Dr. Hubbard spent a recent sabbatical. "There were some old-style people studying microwaves, and some new-style people who knew how to put circuits on chips. Together, we built something that wouldn't ordinarily be built in silicon. It was such a weird mixture of people, but we all got together and made a circuit that looks a lot like the ear." Had he needed convincing of the benefits of cross-fertilization in research, that success would have done it.

Indeed, the interdisciplinary approach is unanimously valued. "We often require tools from someone else's research," says Professor Col-burn, and Dr. Mountain agrees: "We're talking about an incredibly complex organ; we not only need to understand its anatomy but also its mechanical and electrical properties."

Collaboration with other University researchers both inside and beyond the College is integral. To encourage even more interaction, Dr. Colburn's group is moving toward starting an Auditory Center. "With collaboration, we improve the training for graduate students," says Dr. Colburn. "And by organizing ourselves as a center, we'll be able to increase our recognition outside and inside the University. Few people realize how much important research in audition is being done at Boston University."

Most important, however, is that work in the various labs will he synchronized. After all, Dr. Colburn reminds us, "the results we all get ultimately have to be compatible." Or, as Dr. Mountain says, "eventually it's got to be put back into a head." *KA*

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