Long before she was a scientist, Barbara Shinn-Cunningham was a musician, playing piano, then oboe and later the English horn, and her deep love of music led her to study the neuroscience of hearing.

Tuning In

Barbara Shinn-Cunningham taps brains to find and fix hidden hearing loss / BY CHRIS BERDIK

Over the past three decades Shinn-Cunningham, a College of Engineering professor of biomedical engineering, has studied how our brains make sense of sound.

Her lab’s investigations stretch from the precise algorithms of auditory signal processing to the black boxes of cognition and how shifting attention changes the way our brains sort through the daily mix of sounds we encounter.

Recently, she and her colleagues have focused on hidden hearing loss—the trouble many people with “normal” hearing experience when deciphering competing, overlapping sounds, such as a conversation in a crowded room. Hidden hearing loss can be found in those of any age, but it is more common among older people. Indeed, the aging of the baby boomers has spurred interest in the problem.

Shinn-Cunningham calls hidden hearing loss “the most important discovery in hearing research that I have seen in my career.” Eventually, she and her lab team hope to devise a new kind of hearing aid that could alleviate this vexing problem. Spanning cognitive psychology, neuroscience, and engineering to diagnose and treat hidden hearing loss makes for an ambitious agenda, which takes energy, curiosity, and an affinity for collaboration.

Music Meets Math

When Shinn-Cunningham started graduate school at MIT, she envisioned a career designing computers. But once there, she met engineers studying auditory perception. It was a revelation to discover that something like music, which she loved and connected to on an emotional level, could also be understood from the mathematical perspective of an engineer.

“I’d never thought about sound as information that could be studied quantitatively,” she says. “How does sound physically get into the head, and how does the brain make sense of all that information, which eventually leads to those deep, emotional responses?”

Starting at your vibrating eardrum and quickly moving to about 30,000 nerve fibers in your inner ear, every sound you hear is pulled apart by frequency, and then analyzed and reassembled by your brain. Even when competing sounds—the voice of a conversation partner, street traffic, chirping birds—share frequencies, your brain somehow separates them.

The engineering approach to hearing builds precise, mathematical models of how a sound signal is processed, neuron by neuron. As excited as Shinn-Cunningham was to explore that perspective, however, she was also keen to investigate the far murkier, top-down role of cognition.

“The brain has feedback all the way from the cortex back to the brainstem,” she explains. In short, auditory perception isn’t a one-way street. Higher-order brain activities—particularly attention—change how the sound signals are processed in the brain at every level.

The power of attention in hearing was famously demonstrated in the 1950s by the British cognitive scientist Colin Cherry. In a series of experiments, Cherry asked subjects to repeat one of two spoken messages played simultaneously over headphones. People had trouble with this task when both messages (spoken by the same voice)
could be heard in both ears. By contrast, listeners had no problem when one message was simultaneously directed to each ear, because they were able to steer their attention to one ear or the other.

The flip side of this ability was that pretty much nothing about the message in the unattended ear registered—most people couldn't remember a single phrase from the "rejected" message, or notice when it included their name, switched from English to German, or was played backward.

Cherry's findings, now known as the "cocktail party effect," are a centerpiece of Shinn-Cunningham's research agenda, because it is precisely in this interaction between attention and hearing that hidden hearing loss reveals itself. She and her lab team are puzzling out what's going on in our brains during such complex listening tasks. More precisely, they are trying to determine which part of that neural circuitry is breaking down among the 5 to 15 percent of Americans who have "normal" hearing but still tell their doctors they have trouble in crowded, noisy social situations.

Current hearing screenings can't measure this common difficulty, because such tests are based only on our brain's bottom-up ability to detect tones of different frequencies.

During a tour of her lab, Shinn-Cunningham holds up a neural net of 128 tiny electrodes that fit snugly around the heads of research subjects as they listen to tones or words over headphones in a soundproof room. Known as EEG (electroencephalogram), the neural net tracks brain activity in both cortical and subcortical areas as the sounds being processed change or are obscured. The data give researchers a real-time, global look at the listening brain, but Shinn-Cunningham is quick to point out its limits.

"We can extract these big responses to different sounds [with EEG]," she says, "but we know the brain parts we're measuring are changed by attention, and we can't see those effects from the surface of the scalp."

The lab team is also digging into factors that lead to this hearing difficulty. Age would seem obvious, but the data says not so fast. A few years ago, when Shinn-Cunningham, 51, noticed her own growing difficulty with the cocktail party effect, she suggested that one of her graduate students, Dorea Ruggles (ENG'12), do a comparison study of young adults (aged 18 to 34 in the study) and middle-aged people (aged 35 to 55) with normal hearing.

Ruggles, now a postdoctoral researcher at the University of Minnesota, found a small increase in hidden hearing loss among older study subjects overall. But this effect was dwarfed by variability among young adults—some of whom showed no signs of hidden hearing loss while others suffered greatly from it. Why?

"We live in a really loud world," says Shinn-Cunningham. Genetics likely play a role in making people more or less susceptible to hidden hearing loss, but she suspects a noisy lifestyle is a key trigger.

"We can't really test how much noise exposure people have had over a lifetime," she concedes. "But when we do these tests, we ask subjects questions, such as: do you mow the lawn a lot? Do you like loud music? And the people with the most noise exposure tend to be the worst listeners."

Finally, the lab is working on hearing aids that might alleviate hidden hearing loss. Many existing hearing aids can actually make things worse in crowded and noisy social situations, because they simply make everything louder, creating a big blur of noise. It's an engineering approach to a problem that requires something more.

While "directional hearing aids" can be more selective, amplifying only what they're aimed toward, Shinn-Cunningham says they are not likely to help in a lot of social situations where conversations move quickly from speaker to speaker.

Shinn-Cunningham's lab wants to specifically target hidden hearing loss—to create a device for those who don't have a hearing aid, or a diagnosed hearing impairment, but who have trouble hearing in noisy environments, causing embarrassment.

"If we understand what's missing in the signal that somebody with hidden hearing loss is getting in their brain, then maybe we can deal directly with that problem," she says.

Shinn-Cunningham won't get into specifics, citing intellectual property concerns, but in 2015, she and Sharon Kujawa, an associate professor of otolaryngology at Harvard Medical School, were awarded $100,000 in translational research funding to develop just such a device.