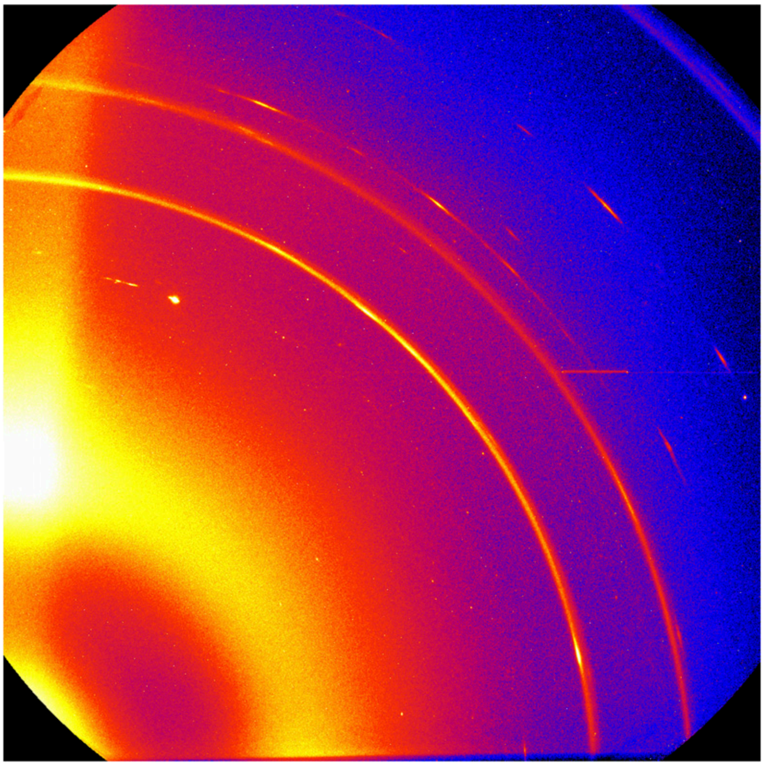
Musicians join scientists to explore data through sound

Carolyn Beans, *Science Writer*

Composer Margaret Schedel grew up with a mathematically minded father who had a fondness for flow charts. "He'd say, 'You can't remember how to do the laundry? Make a flow chart!'" Schedel recalls. Like her father, Schedel was fascinated by computer science, but her dyslexia made programming challenging. "I think I have a logical brain, but one that is a different kind of logic." Today, as a professor in the music department at Stony Brook University in New York, Schedel relies on that logic along with her musical training to help researchers across her university hear their data.

Schedel is one of many musicians and researchers working in data sonification, a field focused on translating data into sound. That might mean sonifying proteins by assigning a chord to each amino acid (1), climate data by increasing pitch with temperature (2), or even neighborhood income levels along a subway line by assigning different sorts of instruments (https://datadrivendj.com/tracks/subway). The end goal: deep insights into data revealed through sound.



A composer and a materials scientist teamed up to sonify the structures of nanomaterials: they converted X-ray scattering data, such as that from a metal alloy shown here, into sounds. Image courtesy of Kevin G. Yager (Brookhaven National Laboratory, Upton, NY).

Hearing Data

Researchers converted data to sound long before there was a name attached to the practice, says John Neuhoff, professor of psychology and neuroscience at The College of Wooster in Ohio, and coeditor of *The Sonification Handbook* (3). Neuhoff cites the Geiger counter as a classic example: "You can't see radiation," he says. "If you'd like to measure it in some way that is handy and immediate, you can convert the radio activity into sound."

Neuhoff says the field became formalized in 1992 with the first meeting of the International Community for Auditory Display (ICAD) at the Santa Fe Institute in New Mexico. Since then, scientists and musicians have continued using sound to supplement or reach beyond visual representations of data. "There are some things the auditory system is better at," explains Neuhoff. "If you have a lot of data over a lot of time, it may be difficult to look at. We're better at timing with our ears than with our eyes."

A lot of sonification, notes Schedel, has taken place in the fields of oceanography and astronomy because they entail large datasets that already have a time component. Schedel advised a music doctoral student, Levy Lorenzo who, working with Stony Brook mathematician Tony Phillips, sonified one month of tidal data from Venice and another month from Ancona, Italy (4). For each piece, Lorenzo translated the two high and two low tides each day into musical notes. As the tide rose and fell, so did the pitch. He played the Venice piece on a single instrument, the marimba (www.math.stonybrook.edu/~tony/tides/venice/venice3000.html). For Ancona, Lorenzo experimented with more complex sound by assigning a different woodwind instrument to play each of the four daily tidal extremes (www.math.stonybrook.edu/~tony/tides/venice/ancona3000.html). Phillips finds tidal data interesting from a mathematical perspective because it follows an almost periodic function: a function that comes close to repeating itself, but never quite does. By sonifying tides, Phillips believes he can illustrate this mathematical concept in a way that is more accessible than data plotted on a graph. "If you listen to it, it's like a song that sort of repeats itself, but not exactly. It keeps changing and keeps changing and keeps changing."

Sometimes data need to be represented to people whose eyes are busy with other tasks, notes Neuhoff.

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A researcher might, for example, write a paper while listening for audio cues indicating that equipment is running properly.

In one effort to facilitate such multitasking, Schedel collaborated with her spouse, materials scientist Kevin Yager of Brookhaven National Laboratory in Upton, New York, to develop a method for sonifying nanomaterials structures (5). Yager used a technique known as X-ray scattering to visualize the structure. Schedel matched different qualities of the structures to different qualities of sound. For example, she increased pitch as atoms were packed more closely together. Schedel and Yager believe researchers could use this approach to audibly screen for errors in nanomaterial structure data collection.

The Sound of Walking

But practical medical applications are also possible. Together with Lisa Muratori, a professor of physical therapy at Stony Brook University, Schedel is using data sonification to develop a tool that could help people with Parkinson's disease correct unsteady gaits.

By attaching 3D motion sensors to a patient's feet, the simple act of walking can generate a lot of data.

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—Carla Scaletti

There are time components (for example, how many seconds it takes for the left foot to swing forward) and spatial components (such as the length of a stride). Muratori collects these data from healthy individuals and from people with Parkinson's disease. Schedel then sonifies that data by matching different components of walking with different aspects of sound. Pitch, for example, goes up and down as the foot lifts up and then returns to the ground. Variation in pitch—the vibrato—becomes wider as steps become more off-centered. "Sometimes I want to know what the whole data looks like: the gestalt," says Muratori. "But sometimes I want to hear something very specific, like when the heel hits on the left side." Data sonification allows her to do both. "It's incredibly powerful," Muratori says.

From a scientific perspective, the project worked well. The unsteady gait of a person with Parkinson's disease could easily be heard in changes in rhythmicity and pitch. From an aesthetic perspective, it was a disaster: a cacophony of alien-like whirs, hums, and buzzes. "I would not want to listen to that," says Schedel. "What do people want to listen to? They want to listen to the music they like." Schedel now uses data from different parameters of walking to distort preexisting music whenever the gait is off. "You get to listen to whatever music you want," says Schedel. "To hear it correctly, you have to walk correctly."

Ultimately, the team would like Parkinson's patients to be able to hear their own data. The researchers are developing lightweight wearable sensors that feed motion data into a smart phone, which will allow individuals to hear, and potentially correct, their gaits in real time. In a pilot study, individuals with Parkinson's disease recognized distortion in music and corrected it using a sliding bar on an iPad screen.* The hope is that these individuals will also be adept at correcting distortion by adjusting their gaits.

Is it Music?

Musicians were involved in data sonification from the start of the field. Not only did they help organize the first ICAD meeting, says Mark Ballora, a professor of music technology at Pennsylvania State University in State College, but they also played a leading role in describing the basic principles of the field: the notions, for example, that sonification allows for sensitivity to multiple streams of information, and the representation of multidimensional data. According to Neuhoff, musicians also have something to offer with respect to usability and aesthetics. "Sonifications that are pleasing to the ear are more likely to be used," he says.

Ballora says his own data sonification work is music. "I've always been more interested in data sonification from a musical sensibility," he says. But Ballora also stays true to the underlying data. "Should you care to listen analytically, you will get information."

For composer and data sonifier Carla Scaletti, data sonification and music have different goals. Data sonification aims to "discover something about the original phenomenon that produced the data," she says. "It's almost like you don't care that it was conveyed by sound. You're trying to hear that underlying structure; whereas for music, you do want people to be aware of the sound."

Scaletti likens aesthetic choices in data sonification to graphic design choices when preparing a chart for a scientific paper. "You choose colors and you choose a font, but all your choices are guided by the goal of wanting to make the data very clear." When Scaletti isn't working on scientific projects, she sometimes uses data in compositions, but she calls those works data-driven music, or just music.

Schedel likes to think each individual project falls on a continuum between science and music depending on the goal. She feels comfortable at both ends of that continuum. "They're so different. It's like, which child is your favorite? They just make different parts of my brain happy." Schedel's Parkinson's disease work is pure science, she says, but she could also envision a more music-focused project where she would attach the same motion sensors to dancers and create a dance beat.

At Stony Brook, Schedel remains in demand. Researchers regularly approach her for collaborations. She's exploring, for example, the possibility of sonifying healthcare records with Stony Brook's Department of Biomedical Informatics. Exactly how that would work isn't yet

*Schedel M, et al. (2016) Interactive sonification of gait: Realtime biofeedback for people with Parkinson's disease. *Proceedings of ISon 2016, Fifth Interactive Sonification Workshop*, December 16, 2016, Bielefeld, Germany.

clear, but Schedel sees potential because doctors and nurses are already trained to use their ears as they work.

Schedel still composes music, but she spends about half of her time on data sonification projects. "I love science, but I just couldn't imagine life without music. This is such a cool way to learn about other disciplines," she says. "I'm able to bring a novel aspect to their research and, ideally, help."

1 Carey J (2016) Science and Culture: Musical genes. *Proc Natl Acad Sci USA* 113:1958–1959.

2 Hansman H (September 21, 2015) . This Song Is Composed From 133 Years of Climate Change Data. *Smithsonian.com*. Available at www.smithsonianmag.com/science-nature/this-song-composed-from-133-years-climate-change-data-180956225/. Accessed March 20, 2017.

3 Hermann T, Hunt A, Neuhoff JG, eds (2011) *The Sonification Handbook* (Logos Publishing House, Berlin).

4 Schedel M, Vallier T (2012) The Data Sensorium: Sonifications. *Music, Mind, and Invention Workshop*. Available at www.tcnj.edu/~mmi/papers/Paper63.pdf. Accessed March 20, 2017.

5 Schedel M, Yager KG (2012) Hearing Nano-Structures: A Case Study in Timbral Sonification. *Proceedings of the 18th International Conference on Auditory Display*. Available at https://smartech.gatech.edu/bitstream/handle/1853/44441/Schedel_ICAD2012.pdf?sequence=1&isAllowed=y. Accessed March 20, 2017.