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CENTER ON HUMAN DEVELOPMENT & DISABILITY
UNIVERSITY of WASHINGTON

CHDD Outlook 2016 Issue #7
News from the Center on Human Development and Disability at the University of Washington

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Using a Computer Model to Improve How Cochlear Implants Perform

by Kate Forster

A cochlear implant is an electronic device that can help provide a sense of sound to individuals with severe or complete hearing loss. It consists of an external component that sits behind the ear and an internal component that is surgically placed under the skin. Unlike hearing aids, which amplify sound, cochlear implants are designed to bypass the damaged cochlea and stimulate the surviving auditory nerve fibers using electrical signals. These signals are then sent by the auditory nerve to the brain, which recognizes those signals as sound. While cochlear implants improve hearing for many people, they do not enable those who have them to hear well in noisy environments. This can lead to social isolation, and it adversely affects education and employment. In addition, cochlear implants are designed to address an individual's particular condition, and one of the biggest challenges for professionals who help design cochlear implants—from bioengineers to audiologists—is to find ways to predict how a cochlear implant will perform before it has been surgically implanted.

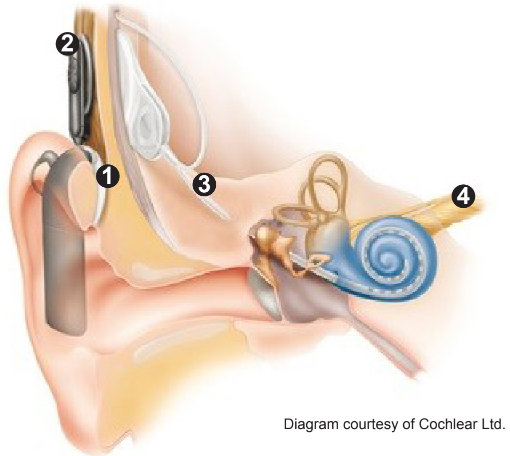

Diagram courtesy of Cochlear Ltd.

Cochlear implant: (1) The microphone and speech processor sit behind the ear. (2) The external transmitter relays information to the receiver that is surgically placed under the skin. (3) Through a wire, electrical signals stimulate the surviving auditory nerve fibers. (4) The auditory nerve sends these signals to the brain.

Jay Rubinstein, M.D., Ph.D., wants to improve the methods that predict a cochlear implant's effectiveness before it is implanted. Rubinstein is the director of the Virginia Merrill Bloedel Hearing Research Center, a professor of bioengineering, otolaryngology/head and neck surgery, and a CHDD research affiliate. From the time he was a graduate student in bioengineering, he has been perfecting a computer model that simulates how a person hears. "At the time, we were trying to predict the response of an electronically stimulated nerve," he said. "We wanted to understand more about how a prosthetic device in the ear would activate the nerve."

As technology has gotten more sophisticated over the years, Rubinstein and his team have been able to make this model increasingly complex. Rubinstein is now pleased to see a graduate student take on the work he started thirty years ago. He is currently working with doctoral candidate Elle O'Brien to take this work further and create a computer model that simulates how a person with hearing loss actually hears. Their goal is to use this computer model to improve the speech processing component of the cochlear implant to get the best possible performance once it has been surgically implanted in a patient. "The way an implant performs varies from person to person," he said. “While we don’t know precisely why this is, we think that this variability is partially related to the pathology of the ear.” Rubinstein believes that if he can simulate the effects of an individual’s particular condition in a computer model, he could validate that this is actually the case. Then, he would be able to use the computer model to predict how an individual would respond to a cochlear implant based on their specific condition. “In the same way we can simulate a neuron in a computer model,” he said, “we can now simulate what happens to the neuron if it’s partially damaged but still functional.” He would then use this model to test how the damaged neuron responds to a variety of auditory stimuli and use the results to improve the speech processing component of the cochlear implant. The speech processor, part of the external component of the cochlear implant, is an algorithm that translates acoustic speech into electrical signals. These signals are then sent to the receiver, part of the internal component of the implant, which then transmits these signals via electrode array to the surviving auditory nerve fibers, which send the signals to the brain.

Jay Rubinstein is working on a computer model that simulates how a person with hearing loss hears. His findings will inform a better cochlear implant design.

Another benefit to using a computer model to simulate how a person hears and responds to auditory stimuli is that it makes cochlear implant research more efficient. “The research we conduct on human subjects to learn the details of how they hear is extremely time-consuming, and it’s incredibly boring for the subjects,” said Rubinstein. “If, in using a computer model, we can speed up the process, we can add immeasurably to what we can learn.”

Rubinstein’s ultimate goal is to restore sound perception to those with profound hearing loss that goes beyond speech, such as music, which is an area where cochlear implants do poorly. However, in order to improve how a cochlear implant performs, he needs to fully understand how the device works, including its limitations. “We’re still trying to understand some of those limitations,” he said. “For example, we have a device that has anywhere from eight to 22 electrodes. In general, the more electrodes that we can represent in the patterns of neural activity, the better the person will hear. But extensive studies have shown that once we go above about eight electrodes, we don’t get any more independent patterns in the nerve. So even though a device might have 22 electrodes, it provides only about 8 channels of information to the ear. We don’t understand why that is, and that’s a critical piece that we need to understand in order to make these devices work a lot better. That is why we’re doing this.”

CHDD is an interdisciplinary center dedicated to the prevention and amelioration of developmental disabilities through research, training, clinical service, and community outreach. CHDD includes the University Center of Excellence in Developmental Disabilities and the Eunice Kennedy Shriver Intellectual and Developmental Disabilities Research Center.

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