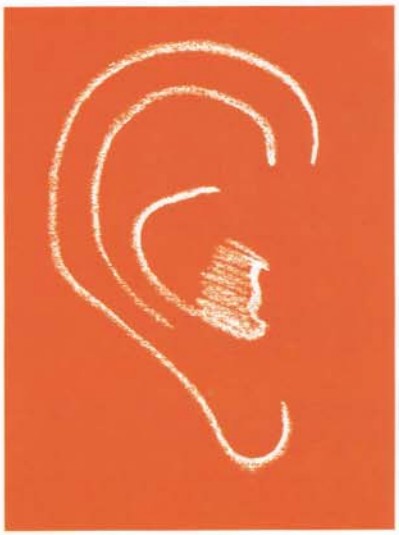


The Brain and Hearing

Hearing researchers have long recognized that the brain perceives speech differently when presented with sound via an auditory prosthesis (or, "bionic ear"), compared with sound via a healthy, "normal" ear. The bionic ear or cochlear implant (CI) is an electronic device that provides hearing sensation to patients with profound hearing loss. Although the CI can approximately represent speech signals, speech patterns delivered by the CI may be dramatically different from normal acoustic patterns. Based on early experience with normal hearing, the brain develops a central speech pattern template of normal acoustic patterns. Speech patterns delivered by the CI have less spectral details and are spectrally distorted relative to those previously developed central speech pattern templates.

After implantation, CI patients typically experience a period of adjustment, during which the brain accommodates the new sounds and speech patterns provided by the implanted device. Initially, most patients find that speech is distorted and sounds strange through the implant. Some patients quickly adapt to their new electronic hearing and are capable of good speech understanding within days or weeks after their initial "hook-up" to the speech processor. However, some patients do not adapt to electronic hearing as quickly. While they may understand some environmental sounds like the phone ringing or a door closing, speech remains difficult to understand. For these patients, auditory rehabilitation may help the brain accommodate the new speech sounds from the implant, or at least accelerate the learning process.

Qian-Jie Fu, Ph.D., and colleagues in the Speech Technology and Hearing Research Laboratory of the Department of Auditory Implants and Perception at the House Ear Institute (HEI) are studying the brain's plasticity and how it may adapt to the distorted sounds provided by auditory prostheses such as the cochlear implant. Dr. Fu is applying this research toward developing rehabilitation tools so that CI patients can get the most benefit from their implant. One such tool is Computer-Assisted Speech Training (CAST), a software program that allows CI patients to conduct auditory rehabilitation using their home computer.

CAST Introduction:

As the science and technology of the cochlear implant (CI) have developed over the past 50 years, the overall speech recognition of CI patients has steadily improved. With the most advanced implant and speech processor, many patients receive great benefit, and are capable of conversing with friends and family over the telephone. However, considerable variability remains in individual patient outcomes. Some patients receive little benefit from the latest CI technology, even after

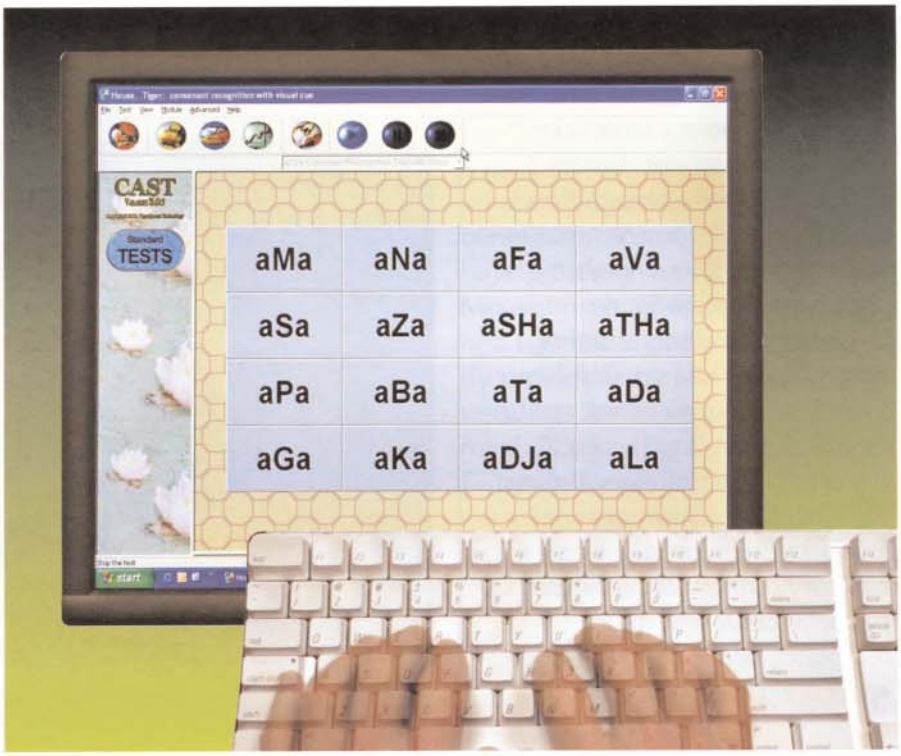
many years of daily use of the device. This variability in patient outcomes is reflected not only in differences in speech recognition performance, but also in the time course of adaptation to speech via electronic hearing. While some patients may easily and quickly adapt to their implant, others may require an extensive learning period. Hearing healthcare professionals acknowledge that cochlear implantation alone may not fully meet the needs of many patients, and that additional auditory therapy may enhance the benefits of the implant device.

Auditory training, an important facet of aural rehabilitation, has been shown to improve speech comprehension and communication among hearing-impaired patients. However, for a variety of reasons, few hearing healthcare professionals routinely include auditory training in the services they provide to CI patients. According to recent statistics, fewer than 10% of practicing audiologists offer patients a comprehensive program of auditory training, compared with 16% in 1990 and 31% in 1980. Time and cost considerations often preclude the use of such therapy. Given the limited number of speech pathologists working with CI patients and the high costs associated with auditory rehabilitation, there has been an urgent need to develop an inexpensive and effective auditory training system for CI patients, especially for those patients who have the greatest difficulty with speech understanding.

CAST Evaluation:

At HEI, much research has been focused on improving the speech recognition performance of CI patients, regardless of the type of implant. For example, Dr. Fu and colleagues have been developing "pre-processing" algorithms, which help enhance the speech signal before it reaches the cochlear implant. However, some of the most impressive gains in CI patients' speech recognition have come from intensive auditory training. Over the past ten years, Dr. Fu and his team have developed a computer-based auditory training program to use in research studies conducted in the laboratory. Recently, the software was modified to evaluate whether training at home, using patients' home computers, could improve CI patients' speech understanding.

Ten CI patients participated in this study, which is supported by the National Institutes of Health (NIH). Training was conducted at home, using a personal computer for one hour per day, five days per week, for a period of one month or longer. The training program targeted simple



vowel and consonant contrasts. During the training, patients heard a word (e.g., bat) and would click on one of the response choices (e.g., bat vs. boat). If they answered correctly, a new word was presented; if they answered incorrectly, auditory and visual feedback was provided, allowing them to compare their choice with the correct answer. As patients' performance with the training improved, the vowel contrasts became more difficult and/or the number of response choices was increased (e.g., bat, bet, bit, bait). Patients returned to the lab regularly to be re-tested for vowel, consonant and sentence recognition.

The results showed significant improvement in all patients' speech recognition performance. On average, vowel recognition scores improved from 24% to 40% correct, and consonant recognition scores improved from 25% to 39% correct, after the training. Although patients' sentence recognition was not directly trained, sentence recognition also improved from 28% to 56% correct. These results suggested that moderate amounts of auditory training, conducted at home using speech-training software, could be effective in improving CI patients' speech understanding. By providing guidance and feedback, the computer-based auditory rehabilitation helped patients' central auditory templates better accommodate speech via the implant.

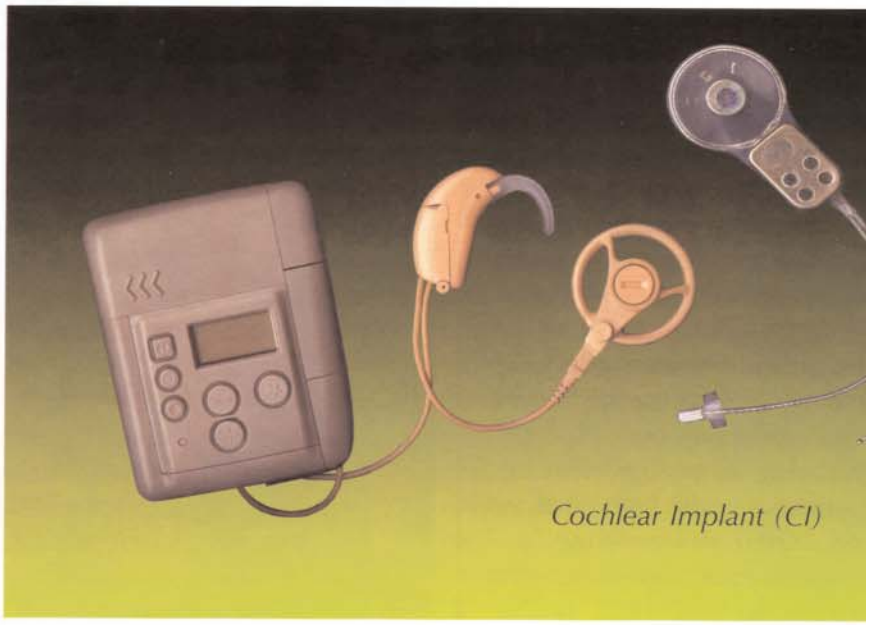
CAST Commercialization:

These promising results have attracted the attention of hearing health professionals. Recently, both Cochlear Corporation and Advanced Bionics Corporation, two major manufacturers of CIs, have entered into license agreements with HEI to translate the research version of CAST into user-friendly commercial software. Melody Medical Instruments Corp. of Taiwan has also entered into a license agreement with HEI to develop a commercial release of the training software for Chinese-speaking CI patients. The first commercial version of this speech training software (titled Sound and Beyond™, from Cochlear Corp.) was released one year ago, and received excellent reviews from CI patients.

CAST Features:

Some of the most appealing features of the CAST software are that CI patients are able to practice at home, and their progress can be easily monitored and shared with their audiologists or speech pathologists. There are many unique features to the CAST software.

First, the software is very flexible, and can be used to train perception of many kinds of sounds, not just speech. In the commercial versions of the software (Sound and Beyond from Cochlear Corp. and Hearing Your Life from Advanced Bionics Corp.) the software has eight different training modules, including: pure tone recognition, environment sounds, talker identification, vowel recognition, consonant recognition, everyday



Cochlear Implant (CI)