AN INFORMATION-THEORETIC APPROACH TO COCHLEAR IMPLANT CODING

Morse R.P.[1] and Stocks N.G.[2]

[1]MacKay Institute of Communication and Neuroscience, Keele University, Keele Staffordshire, ST5 5BG, UK
[2]School of Engineering, University of Warwick, Coventry, CV4 7AL, UK.
r.p.morse@keele.ac.uk

Functional hearing of profoundly deaf people can often be partially restored by direct electrical stimulation of the cochlear nerve by a cochlear implant. In the UK, over 900 adults and 800 children have a cochlear implant; worldwide there are over 30000 implantees. At present, the development of better speech coding strategies for these individuals and future implantees is hindered by the lack of objective design criteria.

An obvious approach to cochlear implant design would be to devise coding schemes that evoke the same patterns of nerve activity with electrical stimulation that are evoked in the normal ear with acoustic stimulation. This can *never* be achieved, however, largely because of the reduced number of healthy nerve fibres present in a damaged cochlear nerve and the limited number of electrodes (typically 16 to 22) that can be surgically implanted into the cochlea. A cochlear implant designer must therefore decide which aspects of the normal pattern of nerve activity are most important for good speech comprehension.

Standard engineering methods, such as frequency analysis or cross-correlation measures, could be used to gauge the ability of a particular coding strategy to encode essential speech features. There are, however, problems with this approach. First, neurones can exhibit a highly nonlinear response; Signal processing techniques such as cross-correlation or frequency analysis are strongly affected by system nonlinearity and, consequently, they do not accurately determine the quality of speech information transmitted by nerve fibres. Second, one has to pre-select which speech features are most essential and whether the coding should be by time or place cues or a judicious combination of both. These choices do not necessarily lead to the best overall speech comprehension.

We propose a rigorous information-theoretic design methodology that will circumvent many of the ad hoc aspects of current coding strategies and may lead to improved speech comprehension for cochlear implant patients. In essence, we propose that a cochlear implant strategy for a particular patient should be designed to maximize the transinformation. By optimizing the transinformation, all essential speech features are enhanced but none are deliberately treated preferentially. Our methodology is based on two propositions. First, that neural encoding of acoustic stimuli is almost optimal in terms of the signal information transmitted to the brain. Second, that random fluctuations (noise) in the normal auditory system, which are much reduced in the deafened ear, are an essential aspect of this near-optimal coding.

In this presentation, we outline the steps required to implement this design strategy. We need to establish that the speech comprehension of a cochlear implantee is strongly correlated with the transinformation in a computational model of their inner ear and cochlear nerve. This proposition will be tested using the Clarion Research Interface, which enables us to present almost arbitrary stimuli to patients who have the Clarion cochlear implant. These experiments, which could greatly benefit patients, also provide an opportunity to study the nature of the neural code in the auditory system.