# Peering inside a cochlear implant user's head

Tiaan Malherbe, Prof Johan Hanekom and Prof Tania Hanekom

**The Bioengineering Research Group at the University of Pretoria has research interests in engineering, medicine and biology. One of the Group's major focus areas is the auditory system, normal hearing and electrically stimulated hearing (cochlear implants for the deaf).**

A cochlear implant is the current treatment of choice for deafness in individuals who are suitable candidates. The device consists of a microphone, an external speech processor that converts the sound input from the microphone to stimulation parameters, a transcutaneous radio link that transmits data and power to the implanted electronics, an implanted stimulus generator, and the multicontact electrode array that is inserted into the inner ear or cochlea. Auditory information is electrically transmitted to the surviving auditory neurons via current injection through the appropriate electrode combinations. On average, speech perception in quiet is around 80%, irrespective of the implant manufacturer.

Despite the success of the intervention, its outcome is still highly user-specific, with benefits ranging from basic rhythm perception without much tonal content to the ability to appreciate music and converse via telephone. The age of the person receiving an implant (Hassanzadeh et al., 2002), the duration of hearing loss (Blamey et al., 1996), electrode design (Rebscher et al., 2007), electrode insertion depth (Finley et al., 2008) and pre-operative variables (Gantz et al., 1993) are some of the factors that influence the implant's perceptual outcome. The precise manner in which these factors interact to produce a user-specific perceptual outcome is still unclear and warrants further investigation. A modelling approach to investigate the factors that affect interperson variability is ideal, since the development of a model in itself provides information about the structure of the system, as well as the parameters that dictate its operation.

Computational models provide a simulated invasive view of the interaction between the

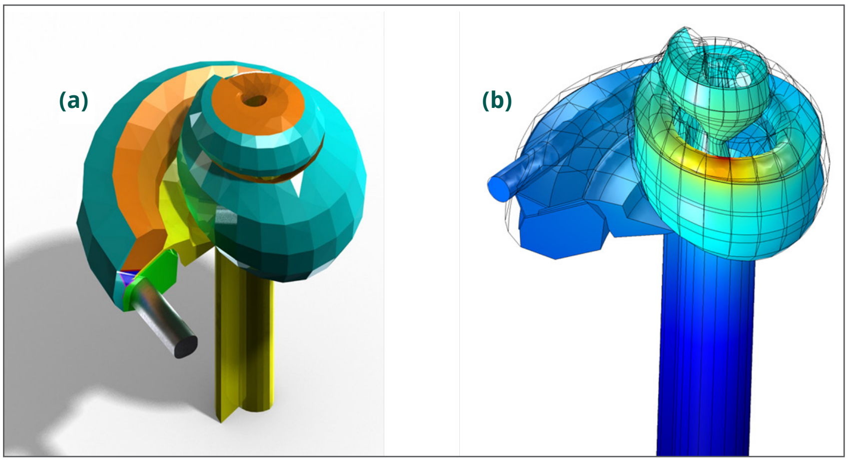
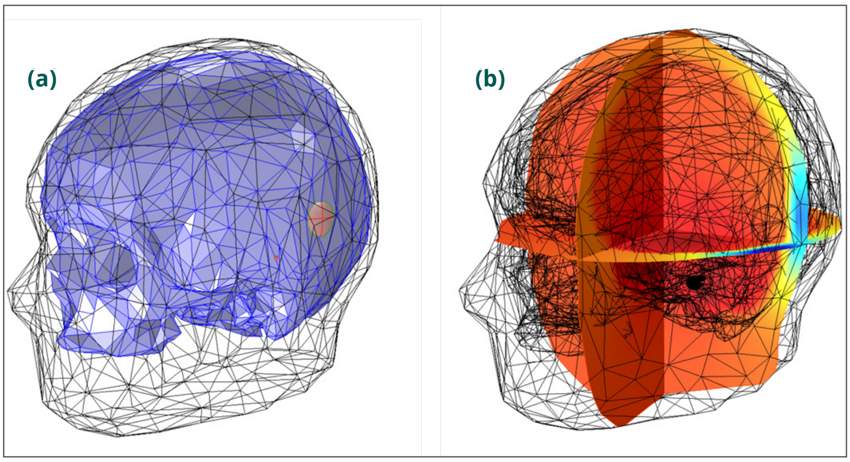



*Figure 1 (a): User-specific computational model of a cochlea showing the electrode array (grey cylinder) protruding from the scala tympani (lower duct of the cochlea shown in green). Figure 1 (b): A finite element solution of the electric potential field inside the cochlea as a result of stimulation with one of the electrodes. The red area indicates the location of the stimulating electrode and has the highest electric potential. The extent to which nerve fibres near this electrode will be excited depends on the specific spatial distribution of the potential field.*

cochlear implant technology and the peripheral auditory system, consisting of the cochlea's anatomy and its neurophysiological environment. This enables researchers to investigate the neurophysiological mechanisms that underlie the interaction between the cochlear implant and the biology (Malherbe et al., 2013). These models provide a computer-generated cochlear environment where neural responses to stimulation via the implant may be controlled through several interdependent parameters and can subsequently be analysed. They also provide a means to simulate an experimental environment that might not be feasible in reality, for example to "measure" (that is, to predict by the model) single-nerve fibre thresholds in the auditory periphery of living human users.

Prof Johan Hanekom and Prof Tania Hanekom from Bioengineering (in the University's Department of Electrical, Electronic and Computer Engineering) have been working in the field of cochlear implant modelling for more than two decades. Recent work on the development of user-specific models for cochlear implantees has been driven by the PhD research of Tiaan Malherbe. The work focuses on the construction of user-specific models for which the geometric parameters are extracted from computed tomography images of the cochleae of these users.

The models incorporate skull and brain volumes to provide an accurate description of current paths among the intra-cochlear stimulation electrodes and the extra-cochlear return electrodes. The potential benefits from the models include a description of the biophysical interface between the device and a specific user's peripheral auditory system, cues to support the customisation of the implant for an individual and diagnostics to probe complications that may arise after implantation, for example, facial nerve stimulation.




→ *Figure 2 (a): Visual representation of the finite element mesh of the full head model showing the external return electrodes in red. Figure 2 (b): Predicted potential fields as a result of intracochlear stimulation on two planes through the model. The cochlea can be seen as a dark area behind the vertical plane and below the horizontal plane.*

## References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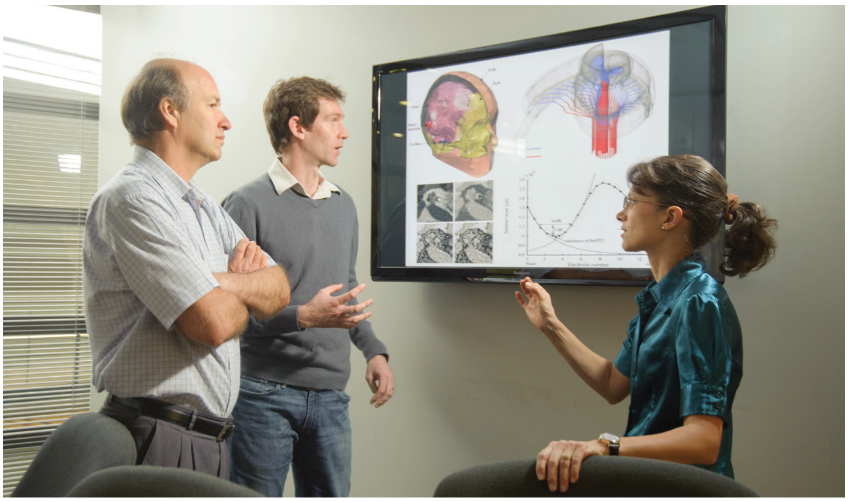

***Prof Johan Hanekom (left)*** *is the Group Head: Bioengineering in the Department of Electrical, Electronic and Computer Engineering.*
***Prof Tania Hanekom (right)*** *is associated with Bioengineering in the Department of Electrical, Electronic and Computer Engineering.*
***Tiaan Malherbe (centre)*** *is a PhD candidate in the Bioengineering Research Group of the Department of Electrical, Electronic and Computer Engineering.*