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Towards a model of electric-acoustic stimulation in cochlear implant subjects with residual hearing

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ABSTRACT

When provided with electric-acoustic stimulation (EAS), cochlear implant (CI) users with residual acoustic low-frequency hearing in the same ear show enhanced speech perception compared to subjects with conventional CIs. However, when electric and acoustic stimulation is presented at the same time, masking between both modalities occurs. To date, it remains unclear at which stage of the auditory pathway these masking effects arise (i.e. at the level of hair cells, the auditory nerve or more centrally).
In order to investigate the underlying mechanisms of electric-acoustic stimulation, we develop a computational model of the spiking activity in auditory nerve fibers (ANFs) triggered by combined electric-acoustic stimulation. We present our approaches to couple existing state-of-the-art models, each of which simulates spiking responses to either electric or acoustic stimuli.

Keywords: cochlear implants, auditory nerve fibers, modelling

OVERVIEW

Thanks to recent improvements in surgical technique and electrode design, it is now often possible to preserve residual acoustic hearing in the low frequencies during the insertion of a cochlear implant (CI) in the same ear. Compared to users of conventional CIs, these subjects receiving combined electric-acoustic stimulation (EAS) show enhanced speech perception, especially in noisy situations (1). However, impeding interactions between both modalities are possible when the cochlea is simultaneously stimulated acoustically and electrically. Masking between electric and acoustic stimulation has been observed in auditory nerve fiber (ANF) spike trains in animals (2) as well as in electrocochleographic (ECochG) responses (3) and psychophysical experiments with humans (4–6), but it is unknown at which stage of the auditory pathway these interactions take place and how they can be taken into account in future CI stimulation strategies.

Here, computational models can be used to improve the understanding of the underlying interaction mechanisms in EAS users. Existing models either simulate ECochG responses phenomenologically (7,8) or calculate ANF spiking for sole acoustic (9,10) or electric (11–13) stimulation. We present a new model, where we coupled the acoustic model of Bruce et al. (2018) with a model of electrically induced spikes in ANFs. Our model shows appropriate responses to acoustic stimulation of remaining hair cells as well as to direct electric stimulation of ANFs.

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