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Modelling the multiphysics of ultrasound neuromodulation

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Low-intensity transcranial ultrasound stimulation (TUS) is poised to become one of the most promising treatments for neurological disorders. Paradoxically, the underlying mechanisms through which TUS neuromodulation operates are still unclear, and a consensus on the identification of optimum sonication parameters still remains elusive. To this end, different models have been proposed to explain how the functional behaviour of brain tissue can be altered in the presence of ultrasound. However, while some do offer promising avenues for the identification of optimum sonication parameters for a given functional target, nearly all focus exclusively on the cellular scale and lack scalability to the organ level. This shortfall naturally makes them difficultly compatible with current models able to predict the level of localised pressure arising in the brain for an ultrasound setup for a given subject (e.g., k-Wave). Here, we propose two approaches to allow for brain scale level functional alteration prediction: i) one tissue level phenomenological numerical model based on homogenisation of flexoelectricity from neuronal membrane scale [1], and ii) one two-scale modelling framework aimed at examining the energy states of neuromodulation under TUS [2]. Both approaches are validated against experimental animal models in the context of white matter neuromodulation and compared together. Overall, both approaches can be considered as two complementary methods – one phenomenological and one energy based – able to assist the clinical community in identifying the optimum sonication parameters in the context of personalised clinical treatment.

REFERENCES

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