PhD Studentship in Computer Science: Analysing and Visualizing Brain-Heart Interactions in Health and Disease Using Visually Explainable AI

Contact
Main Supervisor: alaa.alahmadi@newcastle.ac.uk

Research project

Background: The interaction between the heart and the brain is highly complex, of which sudden unexpected death in epilepsy (SUDEP), sudden cardiac death (SCD) and sudden arrhythmic death syndrome (SADS) are the primary, partly overlapping, clinical scenarios [1,6]. For example, a person with a life-threatening cardiac condition known as long QT syndrome (LQTS) might experience syncope (fainting) due to arrhythmias, which can mimic a seizure [4]. This occurs when the abnormal heart rhythm causes a temporary reduction in blood flow to the brain [4]. This may result in a seizure-like episode that is actually due to hypoxia (low oxygen levels in the brain) rather than abnormal brain electrical activity, and as such LQTS is often misdiagnosed as epilepsy [4,5]. On the other hand, certain seizures in epilepsy patients can lead to sudden death due to mechanisms like cardiac arrhythmias, respiratory failure, or complications from status epilepticus [2,3]. Sudden Unexpected Death in Epilepsy (SUDEP) remains one of the most concerning potential outcomes associated with epilepsy and seizures [3,6].

Aim/Objectives: This interdisciplinary research aims to develop novel, visually explainable AI (integrating computational AI algorithms and data visualisation approaches) to analyse and visualise brain-heart interactions in health and disease, with a long-term vision of preventing sudden cardiac death across wide range of cases. This includes advancing our understanding of the overlapping mechanisms and early signs of life-threatening arrhythmias and other relevant phenomena in neurological conditions such as epilepsy. Furthermore, the research will also advance diagnostic explainable AI algorithms by developing and evaluating new methods to visually explain the brain-heart features at risk of life-threatening conditions, and as such the anticipated algorithms are more likely to be trusted in clinical practice than current 'black box' algorithms that cannot explain their results.

Timeliness & Potential Impact: Data for heart activity (such as electrocardiogram - ECG) and for brain activity (such as electroencephalography - EEG) are becoming widely available now, with large public databases on healthy volunteers and patients. We also hold large and unique study databases in epilepsy that include special types of implanted EEG used in epilepsy. Finally, wearable devices now enable to concurrent measurement of brain and heart in free-living conditions, allowing us to study their interaction in a variety of contexts. With the rise of Machine Learning and AI, we believe that we can now build a comprehensive computational framework to study brain-heart interactions. Abnormal brain-heart interactions also underpin a range of conditions, not limited to epilepsy; therefore, this project may have much wider implications for translation and treatment.

Project Timeline

Supervision Environment

We offer a rich interdisciplinary research environment in both clinical and computational labs. Dr Alaa Alahmadi is a Lecturer in Computational Medicine, based in the Interdisciplinary Computing and Complex BioSystems (ICOS) research group in the School of Computing. She has excellent track record in cardiac monitoring technologies detecting early warning signs of arrhythmias and sudden cardiac death, using integrative knowledge & modelling across multiple complex disciplines. Prof Yujiang Wang is a UKRI Future Leaders Fellow and leads the Computational Neuroscience, Neurology, and Psychiatry (CNNP) lab in the School of Computing. Wang has extensive experience in both EEG, ECG, and wearable sensor analysis, and has a long track record in epilepsy research using computational and data science approaches with over 70 peer-reviewed papers on the topic. Dr Rhys Thomas is an Epileptologist (Royal Victoria Infirmary), Reader in Epilepsy (Newcastle University) and President of the British branch of the International League Against Epilepsy. He has extensive experience in clinical epilepsy research, including studying preventable causes of sudden death unexpected in epilepsy.

Applicant skills/background

This project requires A 2:1 honours degree and/or a merit master's degree, or international equivalent, in Computer Science or a related discipline. Applicants whose first language is not English require an IELTS score of 6.5 overall with a minimum of 5.5 in all sub-skills. The studentship covers fees at the Home rate (UK and EU applicants with pre-settled/settled status and meet the residency criteria). International applicants are welcome to apply but will be required to cover the difference between Home and International fees. International applicants may require an ATAS (Academic Technology Approval Scheme) clearance certificate prior to obtaining their visa and to study on this programme.

References

1. Shlobin, N.A., Thijs, R.D., Benditt, D.G., Zeppenfeld, K. and Sander, J.W., 2024. Sudden death in epilepsy: the overlap between cardiac and neurological factors. Brain Communications, 6(5), p.fcae309.
2. Surges, R., Taggart, P., Sander, J.W. and Walker, M.C., 2010. Too long or too short? New insights into abnormal cardiac repolarization in people with chronic epilepsy and its potential role in sudden unexpected death. *Epilepsia*, *51*(5), pp.738-744.
3. Surges, R., Adjei, P., Kallis, C., Erhuero, J., Scott, C.A., Bell, G.S., Sander, J.W. and Walker, M.C., 2010. Pathologic cardiac repolarization in pharmacoresistant epilepsy and its potential role in sudden unexpected death in epilepsy: a case–control study. *Epilepsia*, *51*(2), pp.233-242.
4. Anderson, J.H., Bos, J.M., Meyer, F.B., Cascino, G.D. and Ackerman, M.J., 2012, November. Concealed long QT syndrome and intractable partial epilepsy: a case report. In *Mayo Clinic Proceedings* (Vol. 87, No. 11, pp. 1128-1131). Elsevier.
5. Crawford, J.M.M.J., French, J.K., Shelling, A.N., Rees, M.I. and Skinner, J.R., 2009. Misdiagnosis of long QT syndrome as epilepsy at first presentation. *An Emer Med*, *54*.
6. Van der Lende, M., Surges, R., Sander, J.W. and Thijs, R.D., 2016. Cardiac arrhythmias during or after epileptic seizures. *Journal of Neurology, Neurosurgery & Psychiatry*, *87*(1), pp.69-74.