Quantum sensing technology and effective computational models for early detection of Alzheimer's disease

Research Theme: Quantum Technologies for Health

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Project Summary:

Recent work has used immersive VR to show that impaired spatial navigation is an early behavioural manifestation of Alzheimer's disease (AD)[1,2,3]. Critically the navigation task involves locomotion but such activity has to date not been compatible with existing functional brain imaging systems that require participants' heads to remain fixed and motionless throughout scanning.

Treatments for AD, with the potential to delay or prevent progression to dementia, are of greatest benefit in the early stages of the condition. Identification of initial disease-related brain dysfunction is central to early detection but requires the combined development of appropriate cognitive tests, current-flow models of deep-brain activity[4], computational models of the neural mechanisms involved[3], and mobile brain imaging technology.

UCL has pioneered the application of quantum sensors known as optically pumped magnetometers (OPMs) for brain imaging [5–7]. In contrast to current bulky scanners which must be climbed into, these sensors are small (about the size of a Lego brick) and allow us to image the brain at fine spatial and temporal scales even during subject movement[8,9].

The aim is therefore to develop the OPM technology for clinical use in AD. This will include, amongst other challenges, concurrent brain imaging and telemetric tracking of participants as they perform diagnostic cognitive tasks; the integration of an immersive VR system within the OPM set-up; the development of analysis pipelines to interpret the changes in brain activity specific to natural spatial navigation. These data would ideally be reconciled with, or tested against, computational models of the neural mechanisms of how we navigate in the world.

This work will benefit from unique access to cohorts at risk of both sporadic and familial AD. In particular, it will leverage existing UCL collaborations relating to the study of the world's largest cohort of autosomal dominantly inherited AD in Colombia.

The ability to identify disease-related brain dysfunction with high spatiotemporal resolution would both aid early detection and provide an imaging outcome measure for tracking disease progression and response to anti-AD therapies years before dementia onset. *The work outlined in this PhD proposal will contribute significantly to these objectives.*

***1**. Howett, D. et al. Differentiation of mild cognitive impairment using an entorhinal cortex-based test of virtual reality navigation. Brain 142, 1751–1766 (2019); **2**. Newton, C. et al. Path integration selectively predicts midlife risk of Alzheimer's disease. Alzheimer's and Dementia (in press) (2024); **3**. Castegnaro, A. et al., Overestimation in angular path integration precedes Alzheimer's dementia. Curr Biol 33: 4650-61; **4**. O'Neill et al., Testing covariance models for MEG source reconstruction of hippocampal activity. Sci. Rep 2021; Sep 2; 11 (1):17615. **5**. Boto, E. et al. Moving magnetoencephalography towards real-world applications with a wearable system. Nature (2018); **6**. Tierney, T. M. et al. Optically pumped magnetometers: From quantum origins to multi-channel magnetoencephalography. Neuroimage (2019) **7**. Barry, D. N. et al. Imaging the human hippocampus with optically-pumped magnetoencephalography. Neuroimage 116192 (2019); **8**. Mellor, S. et al. Real-time, model-based magnetic field correction for moving, wearable MEG. Neuroimage 278, (2023).; **9**. Seymour, R. A. et al. Using OPMs to measure neural activity in standing, mobile participants. Neuroimage 244, (2021).*