Creating Personalised Neuromedicine Using Artificial Intelligence and Brain Modelling

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Disclosures

- I have no relevant financial relationships with commercial interests to disclose.

What is personalised medicine?

- Quantitative, modelling driven insights for a patient’s unique condition

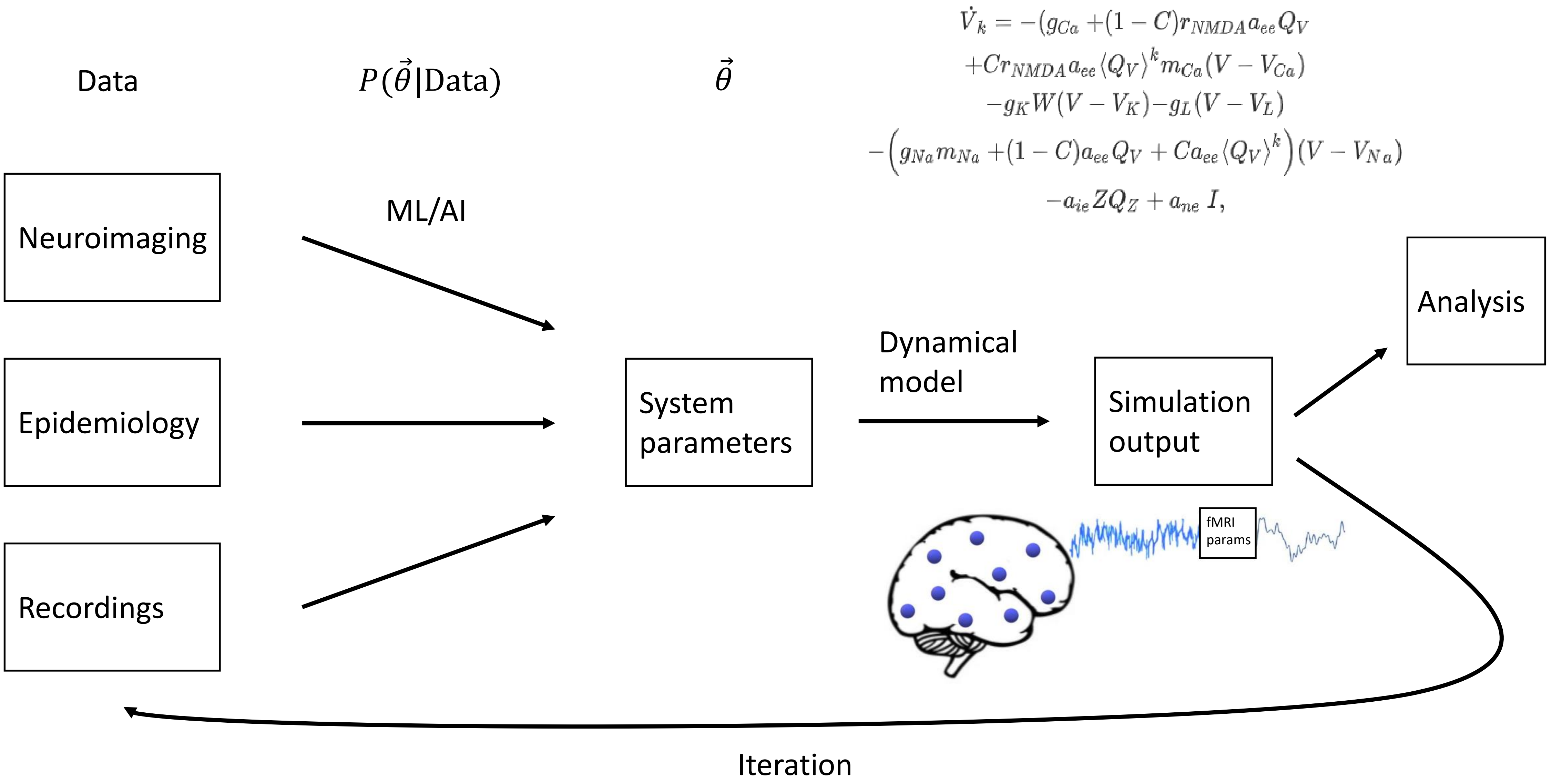


Figure 1. Schematic of a personalised medicine pipeline.

$$\vec{\theta} = \{\theta_1, \ldots, \theta_n\}$$

What is personalised medicine?

- Quantitative, modelling driven insights for a patient’s unique condition

- Explanation – inferred relationships

- Prediction – model output

- Uses simulations, informatics, and other data analysis

Why personalised medicine?

- Psychiatry and neurology are primarily phenomenological

Current state of the art in neurological and psychiatric medicine:

- Causes of symptoms and pathologies are poorly understood
- Inference (observable → disorder)
- Therapeutics of insufficient quality

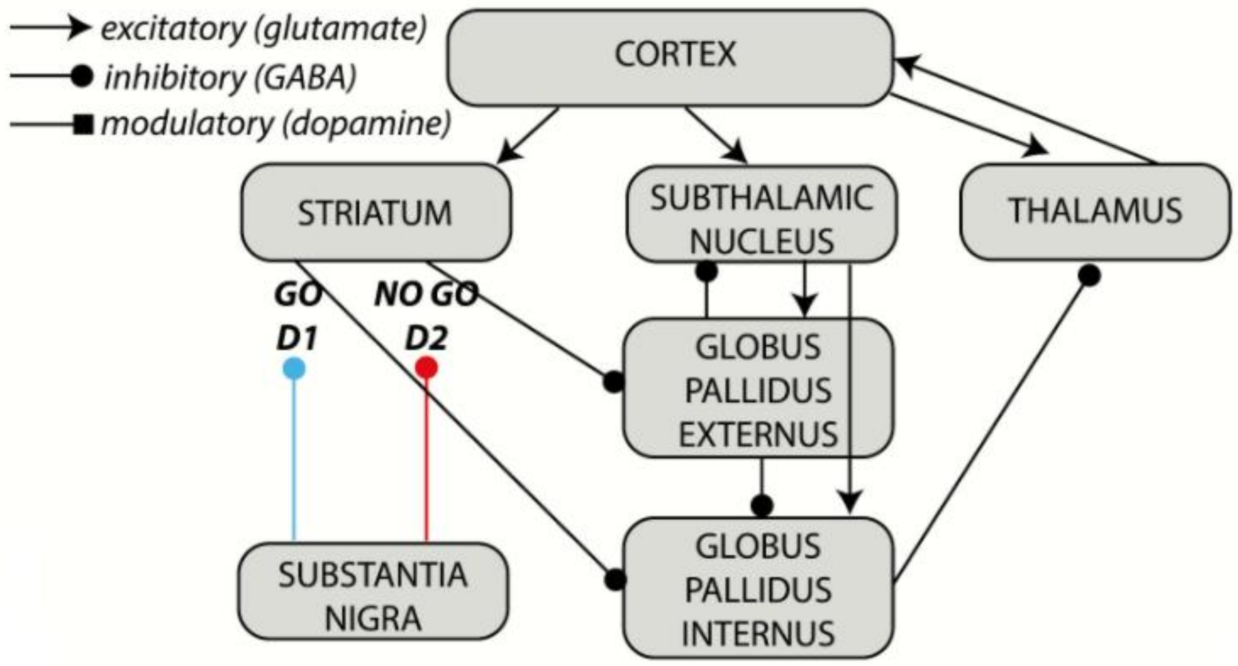
Why personalised medicine?

- Psychiatry and neurology are primarily phenomenological

- Computational modelling provides mechanistic insights

The brain is poorly understood, but modelling helps

- Theory building in neuroscience
- Circuit models (anomaly detection)
- Multiscale models (whole-brain simulation)



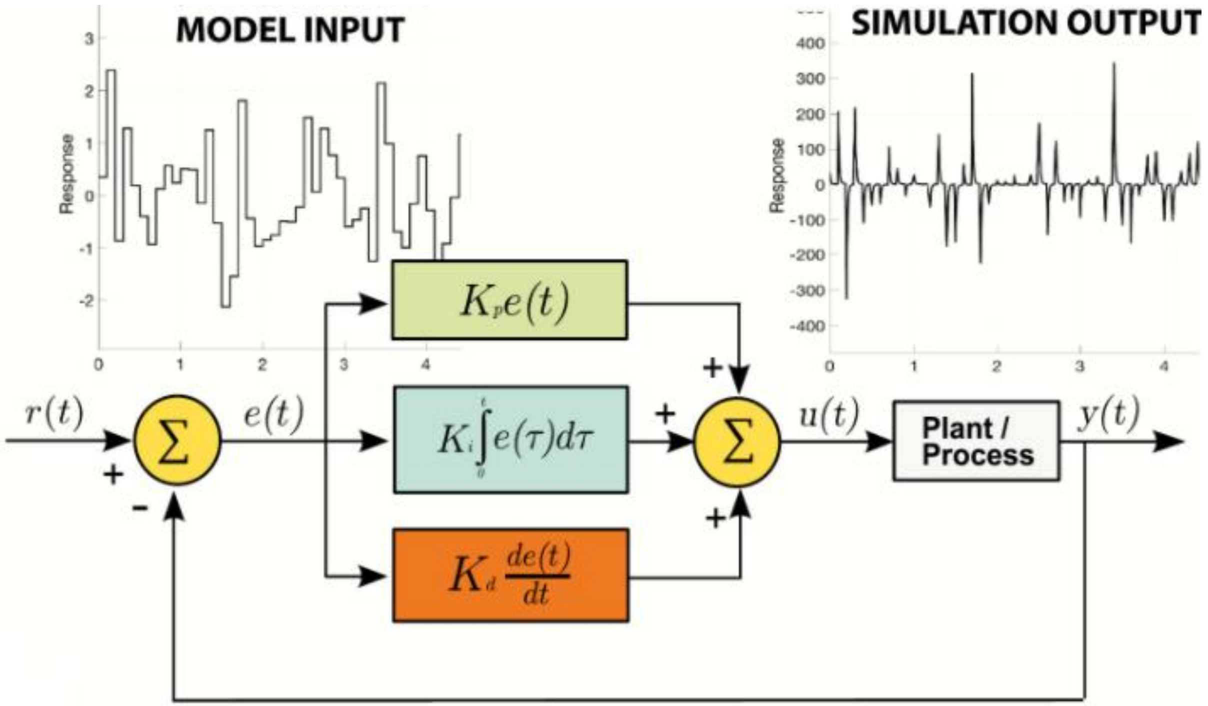


Figure 2. Circuit models of cortical dynamics. Reproduced from Mujica-Parodi and Strey, 2020.

The brain is poorly understood, but modelling helps us understand

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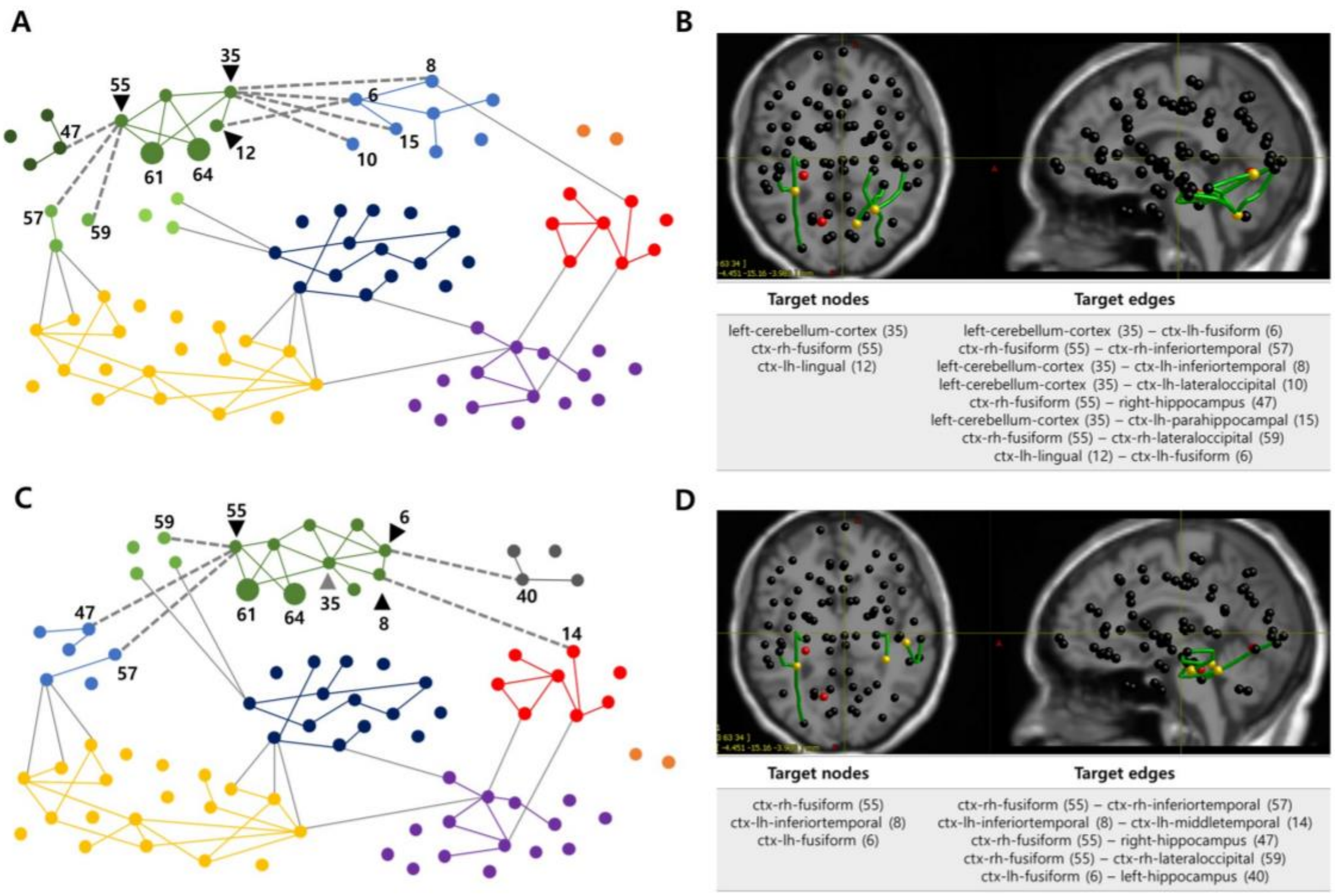


Figures 3. Circuit models of cortical dynamics.
Reproduced from An et al, 2019.

Application of ML

- Models have parameters

- In general:

$$\dot{x} = f(x, \vec{\theta})$$

with $\vec{\theta} = \{\theta_1, \ldots \theta_n\}$ a set of parameters.

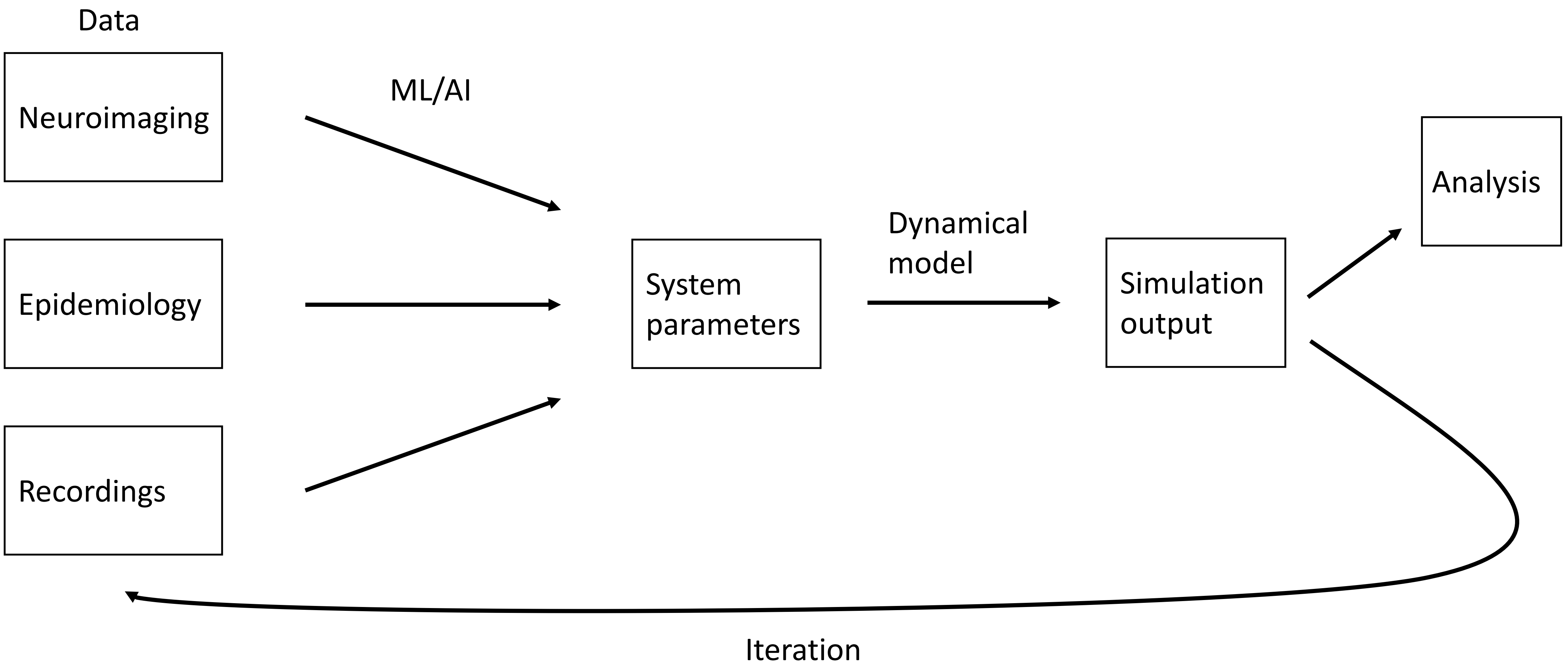
Application of ML

- Models have parameters

$$\dot{V}_k$$
$$= -g_{Ca} + (1 + C)r_{NMDA}a_{ee}Q_V + Cr_{NMDA}a_{ee}\langle Q_V\rangle^k m_{Ca}(V - V_{Ca})$$
$$- g_K W(V - V_K) - g_L(V - V_L)$$
$$- \left(g_{Na}m_{Na} + (1 - C)a_{ee}Q_V + Ca_{ee}\langle Q_V\rangle^k\right)(V - V_{Na}) - a_{ie}ZQ_Z$$
$$+ a_{ne}I$$

Application of ML

- Parameter inference



What can we find?

- Diagnosis, treatment, and prognosis options
- Specific, physical signatures of a disorder
- Mechanistic understanding of how they relate
- Molecular or genetic correlates of behavioural disorder (multiscale models)

A big question

- Brain ageing is notoriously difficult to diagnose, and to stop
- The success of ML in informing models of diseases shows promise
- Looking forward, a model of age-related cognitive decline can shed much needed light on dementia and the ageing process

1. Sanz-Leon et al, 2015. **Mathematical Framework for Large-Scale Brain Network Modeling in The Virtual Brain.** Slide 3, Fig 1, dynamical equations (Larter-Breakspear model). Slide 9.

2. Guest and Martin, 2021. **How Computational Modeling Can Force Theory Building in Psychological Science.** Slide 9.

3. Jordan and Park, 2020. **Birhythmic Analog Circuit Maze: A Nonlinear Neurostimulation Testbed.** Slide 9. Slide 17 (coma).

4. Mujica-Parodi and Strey, 2020. **Making Sense of Computational Psychiatry.** Slide 9, Fig 2.

5. Aerts et al, 2020. **Modeling Brain Dynamics After Tumor Resection Using The Virtual Brain.** Slide 11.

6. An et al, 2019. **Optimization of surgical intervention outside the epileptogenic zone in the Virtual Epileptic Patient (VEP).** Slide 12.

Get in touch!

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