Modelling the emergence of speech and action decisions in the human brain.

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MSc Computational Cognitive Neuroscience

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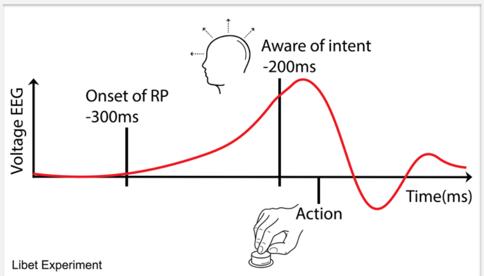
Introduction

The observable neuronal activity which precedes speech and volitional movement (self-initiated) is referred to as *Bereitschaftspotential* more commonly, **Readiness Potential (RP)** [1].

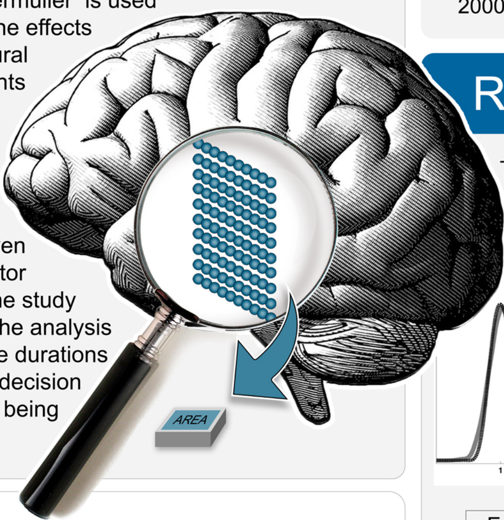


Libet (1980s): The onset of readiness potential therefore intitiation of movement precedes the conscious “urge” (decision) to act.

Alternative paradigm: The neuronal activity preceding the initiation of movement reflects background noise and does not correspond to a decision to act [2].

Primary Research Goal
To investigate the neuronal emergence of volitional acts.

A computational model offered by Garagnani and Pulvermüller is used to study the effects of the neural antecedents that are observed prior to ignitions within the noise-driven accumulator model. The study includes the analysis of the time durations prior to a decision boundary being reached.



Model Architecture used for spontaneous activation. Primary motor (M1), premotor (PM), prefrontal (PF), and primary perceptual (P1), higher perceptual (HP) and perceptual association (PA) areas. Connections between areas are based on known neuroanatomical links [1].

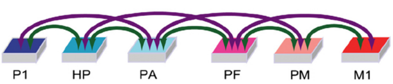


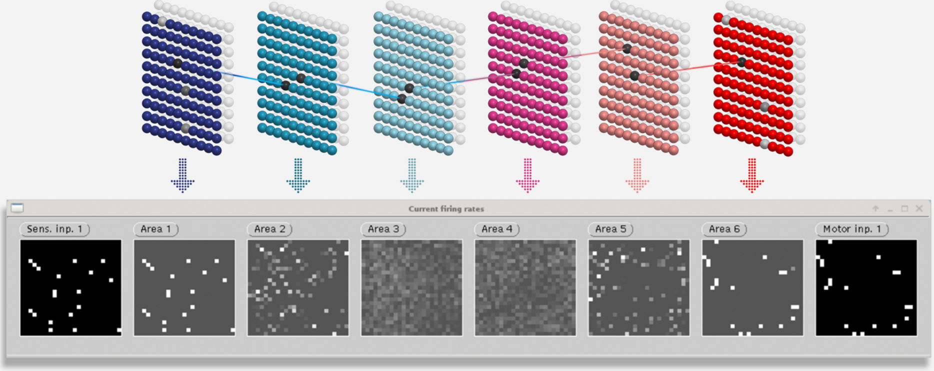
Image by M. Garagnani, F. Pulvermüller

Material and Methods

Model: An existing neuroanatomically realistic neural network trained to learn 12 sensory and motor input patterns.

Architecture: The Neural network model is made up of six areas which corresponding to a cortical region; each area is host to a 25 x 25 layer of interconnected excitatory and inhibitory CA-Cells (neurones) in a grid-like architecture.

Neuronal Dynamic: Synaptic connections between CA-Cells are strengthened based on the foundations of *Hebbian Learning*. The synaptic connections between CA-Cells across the six areas constitute a **Cell Assembly**.



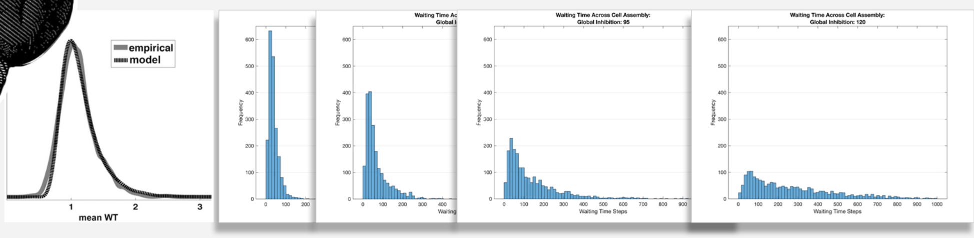
snapshots of network babbling activity (6 areas, 2 input patterns)

Bounded Integration: Input patterns representing both sensory and motor inputs are presented to the network and integrated with internal network activity (noise-driven) until a decision boundary is reached - the spontaneous ignition of a cell assembly.

Parameter Study: Investigating the effect of model parameter changes on RP and spontaneous ignitions of cell assembly across time. Here we take *Global Inhibition*, for each parameter change 2000 spontaneous ignitions are recorded and waiting-time distributions are analysed.

Results (Preliminary)

The spontaneous ignition time step data which is collected from the parameter study is pooled across cell assemblies, and the resulting Poisson-like shape of the waiting times (time step) distribution is visually similar and comparable to empirical data distributions of waiting-times where Libet's experiments have been replicated (Scurger et al).



Empirical

Schurger et al.

Model

There is an effect in incrementally increasing a model parameter (global Inhibition) on waiting time distributions, spontaneous ignitions occur at later time steps, the onset of RP is delayed.

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Future Work

Secondary Research Goal
Computational model fit to empirical data by means of parameter changes to allow predictability of RP and ignition times.

Simulation

Scan the QR code with a mobile device camera to watch a simulation of the model.

[1] Garagnani, M., & Pulvermüller, F. (2013). Neuronal correlates of decisions to speak and act: Spontaneous emergence and dynamic topographies in a computational model of frontal and temporal areas. Brain And Language, 127(1), 75-85. doi: 10.1016/j.bandl.2013.02.001& Dehaene, S. (2012).

[2] Schurger, A., Sitt, J., & Dehaene, S. (2012). An accumulator model for spontaneous neural activity prior to self-initiated movement. Proceedings Of The National Academy Of Sciences, 109(42), E2904-E2913.