The emergence of readiness potential in spontaneous self-initiated action

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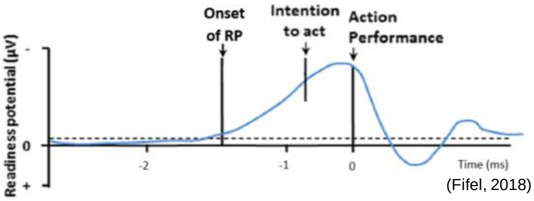
Introduction

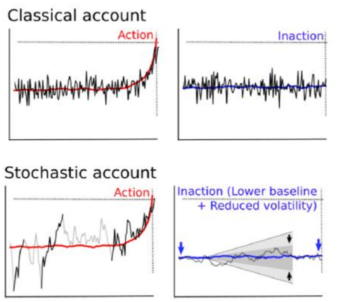
The readiness potential (RP) is a gradual build up in a negative electrical potential of cortical activity that has been observed to precede a voluntary action by a second or more, and has been regarded to be a neural signature of volition (Schurger et al., 2012).



(Fifel, 2018)

The conventional view on the RP entails that it represents action planning and preparation in the supplementary and pre-supplementary motor areas of cerebral cortex (Haggard, 2008).

The RP precedes the time at which participants report being aware of a decision to move, questioning the role of conscious intentions in a motor action (Haggard, 2008).



Travers et al. (2020)

An alternative view proposes that RP is a product of evidence accumulation to an internal threshold for action (Schurger et al., 2012).

Garagnani and Pulvermüller (2013) observed noise-driven spontaneous ignition of cell assemblies (CA) representing an intention of an action in a neurobiologically constrained neural network model. However, the activation of CA occurred too rapidly contradicting empirical findings.

Aims:

1. Using computational simulation data replicate the waiting times (WT) distribution obtained experimentally via the classical Libet experiment.
2. Achieve a reverberation of activity prior to a full activation of CA circuits allowing reproduction of the RP time course observed in experimental data.

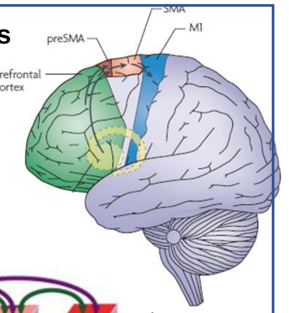
Research question:

Is it more likely that RP reflects accumulation of internal physiological noise rather than a gradual build up in cortical activity that is specific to a self-initiated motor action?

Materials and Methods

Model Architecture:

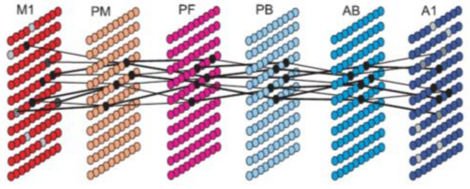
A neural network model will be implemented.
It models six cortical areas –
Primary motor (M1), premotor (PM), prefrontal (PF), primary perceptual (PA), higher perceptual (HP) and perceptual association areas (P1).



(Haggard, 2008)

(Garagnani & Pulvermüller, 2013)

Each area is comprised of excitatory and inhibitory cells that represent neuronal pools and imitate responses and dynamic behaviour of real neurons.



Neuronal dynamics simulated include: local firing activity (membrane potential converted into firing rate); synaptic weights characterising synaptic efficacy; neural adaptation of excitatory cells with a varying firing threshold over time.

Synaptic modification is enabled by means of Hebbian learning – long-term potentiation and depression.

Data analytic strategy:
A two-sample Kolmogorov-Smirnov test was implemented to confirm that the empirical and model data come from a common distribution.

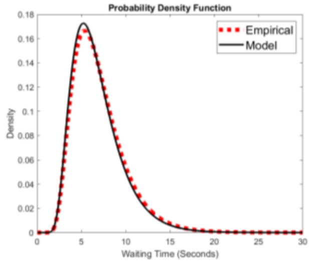
Twelve pre-specified input patterns are presented to the network which are incorporated with spontaneous neuronal firing (noise) and result in a crossing of a decision threshold and spontaneous ignition of CA circuits.

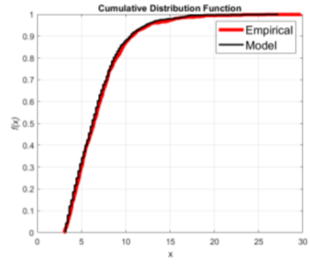
Experimental data:

Schurger et al. (2012) collected WT data obtained via the classical Libet experiment (n=14).

Preliminary Results

Pre-setting the model's parameters (gain=1000; global inhibition=27) and pooling across CA activation resulted in a positively skewed WT distribution that resembled experimental WT distribution.
Comparing the distributions via the K-S test led to accepting the null-hypothesis stating that there is no significant difference between empirical and model WT distributions [D_n=0.047, p=0.131; D_n (0.047) < D_{crit} (0.055)].





References:
Fifel, K. (2018). Readiness Potential and Neuronal Determinism: New Insights on Libet Experiment. *Journal of Neuroscience, 38*(4), 784-786.
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. https://doi.org/10.1016/j.bandl.2013.02.001
Haggard, P. (2008). Human volition: towards a neuroscience of will. *Nature Reviews Neuroscience*, *9*(12), 934. https://doi.org/10.1038/nrn2497
Schurger, A., Sitt, J. D., & 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. https://doi.org/10.1073/pnas.1210467109
Travers, E., Khalighinejad, N., Schurger, A., & Haggard, P. (2020). Do readiness potentials happen all the time? *NeuroImage, 206,* 116286. https://doi.org/10.1016/j.neuroimage.2019.116286

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