A brain-constrained deep neural-network model that can account for the readiness potential in self-initiated volitional action

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The readiness potential (RP) is a gradual buildup of negative electrical potential over the motor cortices prior to onset of a self-initiated movement. It is typically interpreted as having a goal-directed nature, whereby it signals movement planning and preparation. However, a similar buildup can also be observed by averaging continuous random neural fluctuations aligned to crests in their time series [1]. Therefore, an alternative account of the RP is that it reflects ongoing background neuronal noise that has at least a small influence on the precise time of movement onset [2]. While computational modelling studies were used in the past to adjudicate between these accounts, previous attempts did not employ a fully neuroanatomically and neurobiologically realistic architecture, hence falling short of providing a cortical-level mechanistic validation of either theory.

Here, we investigated the stochastic origin of the RP by applying a fully brain-constrained deep neural-network model reproducing real cortical neurons dynamics and the structure and connectivity of relevant primary sensorimotor, secondary and association areas of the frontal and temporal lobes. This model has been previously used to account for the neuromechanistic origins and cortical topography of volitional decisions to speak and act [3]. We used the emergent feature of this neural architecture – its ability to exhibit noise-driven periodic spontaneous ignitions of previously learnt internal representations (cell assemblies, CAs, circuits of strongly and reciprocally connected cells distributed across the entire network) – to mimic spontaneous decisions to act as observed in the classical Libet experiment. Specifically, we recorded the network's activity for 2,000 trials, each trial beginning with a network reset and lasting until the spontaneous ignition of one of the CAs occurred, and used the time interval between trial start and spontaneous CA ignition as a model correlate of waiting times.

We found that the model data accounted well for the experimental waiting-time distribution. Furthermore, in line with the stochastic interpretation of the RP, appropriate calibration of the model parameters resulted in subthreshold reverberation of activity within CA circuits, and averaging across cell assemblies' ignition episodes produced a curve that closely matched the gradual buildup of activity observed in the experimental RP and its onset time.

There are various neurophysiological sources of ongoing noise that result from neural activity. Some of this noise might accumulate and reverberate within previously acquired perception-action circuits, and, hence, produce spontaneous action. The present simulation results, obtained with a fully brain-constrained neural architecture, provide further support for this alternative view, placing the classical explanation of the RP further under scrutiny.

References

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