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Computations in the cerebellum granular layer: timing, plasticity and logical operators

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ABSTRACT OF THE TALK

Part 1: Timing and plasticity in the cerebellar network: focus on the granular layer

Two of the most striking properties of the cerebellum are its control in timing of motor operations and its ability to adapt behaviour to new sensorimotor associations. Here, we propose a ¡ time-window matching¡± hypothesis for granular layer processing. Our hypothesis states that mossy fiber inputs to the granular layer are transformed into well-timed spike bursts by intrinsic granule cell processing, that feed-forward Golgi cell inhibition sets a limit to the duration of such bursts, and that these activities are spread over particular fields in the granular layer so as to generate ongoing time-windows for proper control of interacting motor domains. The role of synaptic plasticity would be that of fine-tuning pre-wired circuits favouring activation of specific granule cell groups in relation to particular time-windows. This concept has wide implications for processing in the olivo-cerebellar system as a whole.

Part 2: Logical operations in neuronal ensembles of the cerebellum granular layer network

The cerebellum granular layer has been long hypothesized to perform combinatorial operations on incoming signals (Marr, 1969; Albus, 1971). In this study, voltage-sensitive dye (VSD) optical recordings have been used to investigate activity in granule cell ensembles. Simultaneous activation of two mossy fiber bundles with partially overlapping excitation fields caused either summation or, conversely, suppression of the responses in different areas revealing coincidence detection and pattern separation predicted by theoretical studies. The sharp transitions characterizing the switch between active and inactive states suggested that activity in neuronal ensembles could be interpreted in terms of logical operations. Whereas response summation corresponded to associative operators like OR, response cancellation pertained to exclusive operators like XOR. In artificial neural networks, XOR requires that the inhibitory circuit becomes dominant upon conjoint stimulation. Consistently, the exclusive operator of the granular layer activated with a delay reflecting the time needed to start feed-forward inhibition in the mossy fiber ¡ú Golgi cell ¡ú granule cell loop and was prevented by GABA-A receptor blockers. Logical operators implement adaptable spatio-temporal filters endowing the cerebellum input stage with extended computational capabilities that could improve pattern-detection in Purkinje cells.