Intrinsic brain activity and sensory coding in the rodent whisker somatosensory system

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The brain uses approximately 20% of the body energy and, in the gray matter, about 75% of the energy is spent to support neural signaling. Surprisingly, it is estimated that only less then 10% of this energy budget is spent for stimulus-evoked neural activity, while the rest is for intrinsic (spontaneous), self-generated activity. This raises a central question for modern neuroscience: *if so much energy is spent on intrinsic activity, what is the function of it? And does it have anything to do with information processing and behavior?*

One clue to solving this puzzle is that intrinsic and sensory-driven activities are surprisingly similar, as it emerged from functional magnetic resonance imaging (fMRI) and multi-site electrophysiology. A current hypothesis is that intrinsic 'resting state' activity provides on-line task-relevant *priors* of neural activity which are shaped by continuous learning during development and experience, and whose function is to offer an internal model of the sensory environment to formulate promptly and effectively behavioral responses (Ferezou and Deneux, 2017). Much is being learned about the mapping of sensory inputs in the brain cortex. Whether intrinsic neural activity in the sensory cortex really represent priors of sensory-evoked responses and whether this activity is used to shape neural coding of sensory perception (Panzeri et al., 2017) remains a fully open question (Luczak et al., 2015).
Furthermore, if spontaneous activity represents behaviorally relevant information learned during development through experience, cellular mechanisms of learning shall be linked to changes of systems level patterns of intrinsic activity. However, such a link between cellular and systems level has never been demonstrated. An intriguing observation by Canals et al. (2009) shows that electrical stimulation of mouse hippocampus with a pattern that induces long-term potentiation (LTP) causes activations of connected remote regions (e.g. contralateral hippocampus and medial prefrontal cortex, PFC). In contrast, this does not happen when the stimulation is matched in frequency and amplitude, but not temporally patterned to induce LTP. Hence these findings suggest a potential link between LTP patterns, known to induce synaptic changes, and long range functional connectivity.

We want to explore these hypotheses in a series of rodent experiments using leading-edge approaches of high-density electrophysiological recording and stimulation, as well as optical imaging and fMRI. We plan to show that stimulus-evoked activity is replayed in spontaneous activity patterns at the level of micro-circuitries in the sensory cortex and that stimuli inducing synaptic plasticity will also induce changes in correlated spontaneous activity.

References

Ferezou, I., Deneux, T., 2017. Review: How do spontaneous and sensory-evoked activities interact? Neurophotonics 4, 031221. https://doi.org/10.1117/1.NPh.4.3.031221
Luczak, A., McNaughton, B.L., Harris, K.D., 2015. Packet-based communication in the cortex. Nat. Rev. Neurosci. 16, 745. https://doi.org/10.1038/nrn4026
Panzeri, S., Harvey, C.D., Piasini, E., Latham, P.E., Fellin, T., 2017. Cracking the Neural Code for Sensory Perception by Combining Statistics, Intervention, and Behavior. Neuron 93, 491–507. https://doi.org/10.1016/j.neuron.2016.12.036
Canals S, Beyerlein M, Merkle H, Logothetis NK (2009) Functional MRI evidence for LTP-induced neural network reorganization. Curr Biol. 19:398-403. doi: 10.1016/j.cub.2009.01.037.

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EXPERIMENTAL DATA:

To be acquired	x
Already acquired (ready to be used)	x

METHODOLOGY

We will focus on the mouse somatosensory barrel cortex (anaesthetized and awake), which is characterized by a clear topological mapping of whiskers. Given that fMRI signals best relate to local field potentials (LFPs), we will use an advanced high-density and large-scale neural probe to investigate LFPs dynamics within single barrels and across cortical layers during spontaneous and whisker-evoked activity. We will adopt a multi-modal multi-scale approach. LFPs will be compared to fMRI and optical (calcium or voltage-sensitive dye) imaging to explore correlations between the activity in the single barrel cortical microcircuit, activity propagation across the somatosensory cortex and how this influences connected brain regions according to the rodent fMRI functional connectivity. To assess the role of synaptic plasticity we will induce LTP in the barrel through rhythmic whisker stimulation, which has been recently shown to efficiently induce synaptic LTP in layer 2/3 (L2/3) pyramidal cells in the absence of somatic spikes.

ETHICS COMMITTEE:

Obtained	
Conditioned submission	Expected time response (in months): 4 months
Not required	