Processing of complex tactile scenes in the somatosensory system of the rat: electrophysiological, imaging and computational approaches

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The tactile sensations mediated by the whisker-to-barrel cortex system allow rodents to efficiently detect and discriminate objects and surfaces. The temporal structure of whisker deflections and the temporal correlation between deflections occurring on several whiskers simultaneously vary for different tactile substrates. We hypothesize that tactile discrimination capabilities rely strongly on the ability of the system to encode different levels of inter-whisker correlations.

To test this hypothesis, we generated complex spatio-temporal patterns of whisker deflections during electrophysiological recordings in the barrel cortex, the ventro-posterior medial (VPM) nucleus of the thalamus and the trigeminal ganglion. A piezoelectric-based stimulator featuring 24 independent and fully adjustable whisker actuators was built for this purpose (Jacob et al., 2010).

Using this stimulator in anesthetized rats, we have previously shown that cortical neurons exhibit direction selectivity to the apparent motion of a multivibrissal stimulus (i.e. an emerging property of the global stimulus), uncorrelated to the local direction of individual whiskers (Jacob et al. 2008). Since a certain level of multiwhisker integration has been reported in the VPM, the nucleus relaying tactile information to the barrel cortex, we showed that emergent properties of multiwhisker stimulations are already coded by VPM neurons although to a lesser degree than in cortex (Ego-Stengel et al., 2012). We are currently exploring the global organization of this property in layers 2-3 (a global supra-barrel map) through voltage-sensitive dye imaging in the mouse.

Finally, we applied a reverse correlation approach to this problem by using Gaussian white noise stimulation on 24 whiskers and progressively varying the level of temporal correlation among them. Using a model-based analysis (spike-triggered covariance and L-NL models) for various levels of inter-whisker correlation, our recent findings (Estebanez et al., 2012) show that neuronal cortical networks implement coexisting coding schemes to cope with the varying statistics of the tactile sensory world. We propose a simple and comprehensive framework that not only accounts for most of the previous reported phenomenology of multiwhisker interactions but also provides a physiological role for this functional selectivity in terms of local contrast and global motion detection.