Encoding and processing of primary sensory variables by the rat vibrissal/trigeminal system

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Rats are nocturnal, burrowing animals that use their vibrissae (whiskers) to tactually explore the environment. Using only its whiskers, a rat can determine object size, shape, orientation, and texture. This makes the rat vibrissal system an excellent model to explore the structure of movements that subserve sensing. I will describe recent experiments in our laboratory that have aimed to understand neural processing in the vibrissal system from the outside-in. I will walk through our laboratory's suggested answers to the following questions:

1. What are the primary mechanical variables sufficient for three-dimensional feature extraction by the whiskers? We suggest that these variables are angular position, angular velocity, and rate of change of moment (torque) at the whisker base. I will show results from a hardware model to demonstrate that these variables are sufficient for feature extraction.

2. How are these variables encoded by the electrical activity of neurons in the first stage of neural processing? In a re-analysis of data from Jones et al. [1] we have found evidence that neurons of the trigeminal ganglion use a state encoding scheme to represent pair-wise combinations of the mechanical variables identified above.

3. How are the variables transformed in the second stage of neural processing, and why might they be transformed in this way? We hypothesize that neurons with multi-whisker receptive fields in the trigeminal nuclei help to compute the relationship between spatial and temporal gradients generated as the animal moves its sensory surfaces through the environment. These gradients, expressed as the complete derivative, are computed based on the animal's own velocity, and provide an inviolate mathematical description of information flow over moving sensory surfaces. Computing the complete derivative at multiple spatial and temporal scales would allow the animal to predict the stimulus that it will measure in the next sensory instant, conferring tremendous survival advantage.

References

[1] Jones LM, Depireux DA, Simons DJ, Keller A (2004) Robust temporal coding in the trigeminal system. Sc*ience* 304:1986-1989.