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Signal processing in posterior-canal bouton vestibular primary afferents

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The labyrinth of most vertebrates contains three nearly orthogonal semicircular canals that are primarily sensitive to angular head acceleration in their respective planes. Head rotations are detected by mechanosensitive hair cell within each canal, whose receptor potentials modulate the firing patterns of primary afferents that transmit signals to the CNS via the VIII nerve.

Empirical studies show that the discharge statistics and response dynamics of vestibular afferents differ depending on the type and location of the hair cells they innervate. In the turtle, the type of hair cell and structure of innervating afferents vary depending on sensory surface location; type I and II hair cells are found in the central zone (CZ) and are innervated by calyx (C), dimorphic (D) and bouton (B) afferents, while only type II hair cells innervated by bouton afferents are present in the peripheral zone (PZ). Bouton afferents located near the canal wall (BP) have regular discharge statistics, and have small gains and phase leads with respect to angular head velocity, whereas B units close to the canal center (BT) have irregular discharges and have large gain and phase leads. Calyx and dimorphic units both have irregular discharge patterns and intermediate gain and phase leads. Perhaps because of their unusual morphology, considerable attention has been paid to signal processing by calyces. However, few studies have examined hair cell-to-afferent signaling in bouton afferents, even though they are the only terminal type found in fish and amphibians and they are a significant population in the semicircular canals of mammals, reptiles and birds.

We are studying signal processing in bouton afferents from the peripheral zone of the posterior canal of the turtle, in particular the contrast between BP and BT cells. We have to date obtained morphological reconstructions of two intra-axonally filled electrophysiologically characterized cells, one BT and one BP unit, that differed substantially in their morphology; the BT unit had 60% more boutons than the BP unit (40 vs 25), it had a larger collection area (5000 vs 3000 μm^2) and a larger projection along the wall to center axis (125 vs 60 mm). These results are consistent with previous reports. We used the above morphologies to construct multi-compartmental models in NEURON. At present, we assume one synapse per bouton. We adjusted independent Poisson vesicle release rates and synaptic conductances to match experimental reports, and incorporated fNa and KDR type voltage-gated channels in axonal compartments. Preliminary results under resting conditions indicate firing patterns consistent with experimental reports in terms of firing rates and the CV of interspike intervals. Preliminary results also indicate that terminal morphology has a measurable influence on discharge regularity as measured by the CV of interspike interval distributions, but the differences are smaller than the measured differences for these units, suggesting that other variables (e.g., number of synapses/bouton; channel kinetics) interact with morphology to shape discharge statistics. Simulations of dynamic behavior are in progress.