BIOMEDICAL ENGINEERING
Carnegie Mellon University

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Doherty Hall A302

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Neural Representations of Natural Self Motion: Implications for Perception & Action

Abstract: The vestibular system detects self-motion and in turn generates reflexes that are crucial for our daily activities, such as stabilizing the visual axis (gaze) and maintaining head and body posture. In addition, the vestibular system provides us with our subjective sense of movement and orientation in space. The loss vestibular function due to aging, injury, or disease produces dizziness, postural imbalance, and an increased risk of falls – all symptoms that profoundly impair quality of life.

In this talk, I will describe how the brain encodes vestibular information in natural conditions. Notably, our work has established the relationship between neural variability, detection thresholds, and information transmission in the vestibular system. In addition, we have established how early stages of processing process vestibular stimuli and integrate them with extra-vestibular cues – for example proprioceptive and premotor information to ensure accurate perception and behaviour. Our experiments have revealed that while vestibular afferents respond identically to externally-generated and actively-generated self-motion, this is not the case at first central stage of sensory processing. Neurons mediating the vestibulo-spinal reflexes, as well as ascending thalamocortical pathways, are robustly activated during externally-generated motion, however their sensory response are cancelled during actively-generated movements. Our work has further revealed that this cancellation of actively-generated vestibular input occurs only in conditions where the actual sensory signal matches the brain's internal estimate of the expected sensory consequences of active movement. Moreover, when unexpected vestibular inputs becomes persistent during voluntary motion, a cerebellar-based cancellation mechanism is rapidly updated to re-enable the vital distinction between self-generated and externally-applied stimulation to ensure the maintenance of posture and stable perception. In contrast, vestibular pathways mediating the vestibulo-ocular reflex, employ a different strategy. In this pathway, head velocity is robustly encoded whenever the goal is to stabilize gaze, but when the goal is to voluntarily redirect gaze an efferent copy of the gaze command suppresses the efficacy of this reflex pathway. Taken together, these findings have important implications for understanding the neural basis of perception and action during self-motion.