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A Virtual World for a Fish

Deciphering How the Brain Integrates Sensory Information to Control Movement

Understanding how the brain integrates sensory information to control movement and navigate through the environment is a fundamental challenge in neuroscience. Our research combines quantitative behavioral experiments, brain-wide functional imaging, and computational approaches inspired by statistical physics to investigate how neural circuits coordinate sensory processing and motor actions. In particular, we are interested in how the brain integrates visual, vestibular, and motor-related signals to maintain posture, control movement, and construct internal representations of the surrounding world. The small size and optical transparency of adult *Danionella* fish offer a unique opportunity to investigate these questions while recording neural activity across the brain.

This internship aims to develop a closed-loop virtual reality system integrating visual and vestibular feedback during swimming in adult *Danionella*. Conventional visual virtual reality systems lack vestibular feedback, creating a sensory conflict between visual motion and the absence of corresponding physical movement. By combining real-time tracking of swimming behavior with controlled rotational stimulation and visual feedback, the proposed system will reproduce more naturalistic sensorimotor interactions, allowing fish to navigate spontaneously in a virtual environment.

As a first step, the student will characterize the vestibulo-ocular reflex (VOR) in an open-loop configuration to assess the functionality of the semicircular canals in adult *Danionella*. In a second step, the student will implement a closed-loop system in which visual and vestibular stimulation are dynamically adjusted based on real-time high-speed measurements of tail movements during swimming. **The ultimate goal is to establish a virtual reality platform that reproduces coherent multisensory feedback during active locomotion.**

This internship can serve as a starting point for a PhD project investigating the neural mechanisms of sensorimotor integration and spatial navigation. Combining closed-loop behavioral experiments with brain-wide functional imaging and computational modeling will open opportunities to explore how neural populations integrate sensory feedback, predict the consequences of movements, and coordinate behavior, using approaches from dynamical systems theory, statistical physics, and machine learning.