Optimal feeding regulation in noisy environmental conditions

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***Short abstract*—Any organism needs to respond to a spatially and temporally dynamic environment and modulation of behavior assists in favorably exploiting the environment. In the case of simple eating behavior, performing eating motions and obtaining nutrients represent a cost and a benefit, respectively, and optimal exploitation is defined by the maximum of a cost-benefit curve. Models of regulatory strategies can potentially be tested using detailed experimental data and may assist in conceptualizing the data in terms of an optimality principle. Within this framework, the implications of limitations, such as noisy sensory cues or imperfect memory, can be assessed. Here, we introduce novel measurements and analysis tools of eating behavior in the nematode *C. elegans*. We use the observes statistics of eating to compare between models based on different optimality criteria and assess the constraints that could make particular strategies favorable.**

***Keywords*—feeding behavior, optimal regulation, decision-theory, information maximization**

I. Background

THE nematode *C. elegans* is a simple model system with feasible genetics and easily quantifiable behaviors that facilitate high-throughput assays. *C. elegans* feeding depends on the action of a muscular pump, the pharynx. During pharyngeal pumping the nematode sucks in bacterial food and surrounding liquid, expels the liquid, and traps the food [1]. The rate of pumping is thus the primary indicator of food intake. he traditional pumping assay scores a mean rate by counting the number of muscle contractions over short intervals, typically 30-60 sec in duration [3].

To measure the statistics of pumping in detail, we use a microfluidic device that enables continuous measurements of pumping and control of the feeding conditions [2]. We can thus alter food concentrations precisely and assay animals continuously for prolonged periods. In addition, we developed a set of machine vision tools which enable us to automatically obtain times series of pumping events from the raw images. These developments allow us to characterize pumping in a controlled environment and obtain unprecedented quantitative information about the dynamics of this process.

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II. Results

We continuously measure feeding rates in the presence of various concentrations of bacterial food for hour-long periods (the optical density (OD) of the bacterial food ranges between 0.5 and 5) and obtain a time-series of pumping events for each animal. Under these conditions, the distribution of intervals between pumps is approximately bimodal and that brief periods of regular pumping are interspersed with periods in which pumping appears irregular. Moreover, the statistics of pumping depend on the availability of food. Thus, a single mean rate fails to capture the richness of pumping dynamics.

In our assays, the animal can ingest relatively small numbers of (discrete) bacteria through each single pump, such that shot noise can affect individual samples of the environment. We hypothesize that there exists an optimal pumping strategy given a fixed cost per pumping event, a fixed benefit per bacterium, and the possible limitations discussed above. We show that the simplistic approach of memory-based thresholding (i.e., asking at each step if the expected gain would be positive) does not describe the experimental data. In contrast, an information-maximization strategy [4] intrinsically reproduces experimentally observed features such as switches between regular and irregular pumping.

III. Conclusion

Novel tools allow the investigation of eating behavior in more detail than was previously possible. These data can be conceptualized in terms of optimal strategies for sensory-based decision processes given various limitations.

References

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