

Signaling noise coordinates multiple flagella to enhance bacterial foraging with minimal cost to chemotactic response

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In bacterial chemotaxis, transmembrane receptors are clustered in large patches, which amplify input signals via cooperative interactions between receptor complexes. We analyzed the effect of the intracellular localization of the molecular components of the bacterial chemotaxis system on the adaptation dynamics and on the behavior of individual bacteria. We found that in addition to amplifying input signal and input noise, the clustering of receptors also enhances the fluctuations that arise within the adaptation mechanism of this model system. This additional source of noise, however, affects cell behavior mostly on the long time scale of adaptation while having a relatively minor effect on the network's information throughput at shorter time scales. What is the effect of these slow fluctuations on the downstream response of multiple flagellar motors? Interestingly, we found that adaptation noise coordinates the timing of flagellar motor switching events, adequately explaining a classical result from Berg and coworkers that found unanticipated time-correlations between the switching probabilities of adjacent flagellar motors on single cells. Through a series of simulations, we found next that noise-induced motor coordination directly alters the distribution of run lengths and enhances a bacterium's foraging ability. The bacterial chemotactic response and ability to swim towards chemoattractants however was remarkably robust to high levels of adaptation noise. Together, our results indicate that low frequency noise originated within the adaptation mechanism of the bacterial chemotaxis is beneficial to cell behavior because it can enhance foraging with minimal cost to chemotactic response. In the broader context of biochemical signal processing, we have identified a novel mechanism for synchronizing the response of multiple independent downstream effectors through noise. Our results suggest that under certain circumstances biological systems may be evolved to harness signaling noise.