A theory of how active behavior stabilizes neural activity: Neural gain modulation by closed-loop environmental feedback

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Abstract

During active behaviors, motor actions shape sensory input and sensory processings guide future motor commands. Ongoing cycles of sensory and motor processing constitute a closed-loop feedback system which is central to motor control and, it has been argued, for perceptual processes. This closed-loop feedback is mediated by brain-wide neural circuits but how the presence of feedback signals impacts on the dynamics and function of neurons is not well understood. Here we present a simple theory suggesting that closed-loop feedback between the brain/body/environment can modulate neural gain and, consequently, change endogenous neural fluctuations and responses to sensory input. We support this theory with modeling and data analysis in two vertebrate systems. More generally we argue that our results demonstrate the dependence of neural fluctuations, across the brain, on closed-loop brain/body/environment interactions strongly supporting the idea that brain function cannot be fully understood through open-loop approaches alone.