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Title: Architecture for sparse control of the *Drosophila* flight motor system

Abstract: Flies perform rapid maneuvers that require the integration of multimodal information to execute motor commands at rapid timescales. These maneuvers are controlled by roughly 12 synchronous muscles that attach at the base of each wing and are each innervated by single motor neurons that require local mechanosensory feedback and multimodal input from the brain. An informational bottleneck of approximately 400 neurons descending (DNs) from the brain along the neck is responsible for relaying information from the brain to the motor neurons of the thorax. Whereas previous studies characterized the activity of flight muscles independently, the mechanisms by which synchronous motor neurons are controlled to produce flight remain largely unknown.

To address this question, we optogenetically targeted small subsets of these DNs for activation, while simultaneously recording from flight muscles and tracking wing kinematics. We found that small changes in the activity of single pairs of DNs were sufficient to regulate the activity of discrete groups of steering muscles, with differing attachment sites and effects on aerodynamics, suggesting that motor neuron recruitment may be coupled. To better understand mechanisms employed by synchronous flight muscles on a population level, we used a genetically encoded calcium sensor to record simultaneously from the nearly complete population of synchronous muscle during tethered flight and in response to an array of visual stimuli. We performed pair-wise cross-correlation analyses of the activity of each of the muscle pairs, to assess their functional connectivity relative to kinematic outputs and visual inputs. Across different stimuli and kinematic outputs we noticed persistent and unique patterns of correlated muscle activity, deemed motor pools. Together, our data indicate a highly coordinated recruitment of motor neurons for specific flight behaviors and allow us to posit kinematic network motifs from which we can begin to infer potential network models. Our ongoing analysis is aimed at determining whether flight motor commands can be represented in a ‘reduced set of signals’: muscle synergies, which may serve as a mechanism of simplifying the control of this complex biological motor pattern.