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Identification of neural circuits required for spontaneous behavioral variability

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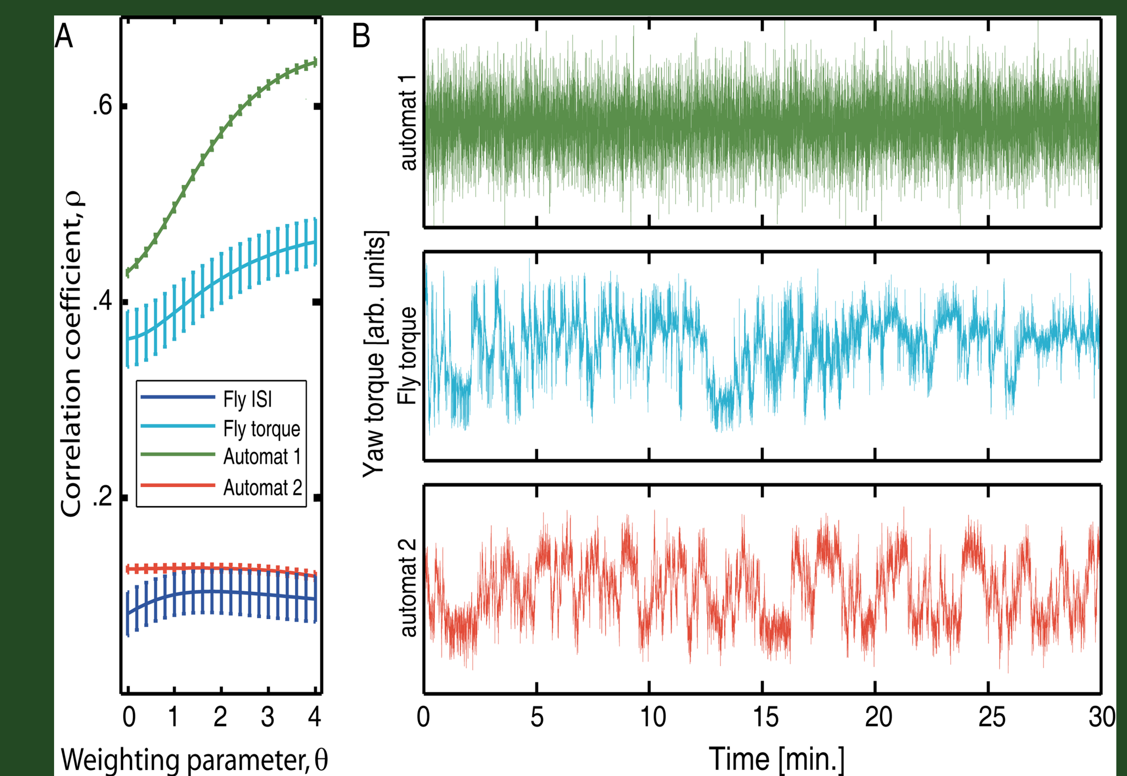
1. Abstract

Even in the absence of external stimuli, brains are capable of initiating spontaneous actions. Spontaneous turning attempts (yaw torque) initiated by Drosophila fruit flies tethered at the torque meter, are not completely governed by random noise in the brain but generated and controlled by intrinsic circuits (Maye et al. 2007). This conclusion is based, among other analyses, on nonlinear forecasting analyses (S-Map procedure) detecting a nonlinear signature in the temporal structure of the torque data. However, nothing is known about the underlying circuits and the neurobiological mechanisms for generating spontaneous actions.

We used the Gal4/UAS system to silence candidate neural circuits in the fly brain, by expressing tetanus toxin light chain (TNT-E) to prevent synaptic vesicle fusion. Yaw turning behavior of tethered flies was recorded with the wingbeat analyzer; the environment of the fly was kept spatially homogeneous and temporally constant, preventing the fly from perceiving any stimuli which might elicit turning behavior. Candidate lines expressing mainly in the central complex and mushroom-bodies were measured. S-Map analysis suggests a defined subset of central complex neurons to be involved in generating spontaneous behavior, while the mushroom-bodies seem not to play any role. Computing the power spectrum of the yaw torque signal from each candidate line revealed that the S-Map phenotype is not due to irregular oscillatory behavior. Automated detection of yaw torque spikes (the equivalent of body-saccades in free flight) did not reveal any significant difference from control strains in the affected candidate lines, suggesting that the general behavioral repertoire of turning behavior is unaffected by the TNT-E expression.

We will present a detailed behavioral characterization of the candidates along with an antibody-based expression analysis of the most interesting lines.

2. Evidence for nonlinear behavioral variability in a constant stimulus situation



*Maye et al (2007).PLoS ONE 2(5): e443

Fig:1 A - S-Map results of fly inter saccade interval (ISI) and raw yaw torque series. Raw yaw torque exhibits a stronger nonlinear signature than ISI data.
B - Sample torque trace from a fly and data from two different parameter settings of a software agent.

3. Screening candidate lines expressing tetanus toxin light chain for a decreased nonlinear signature

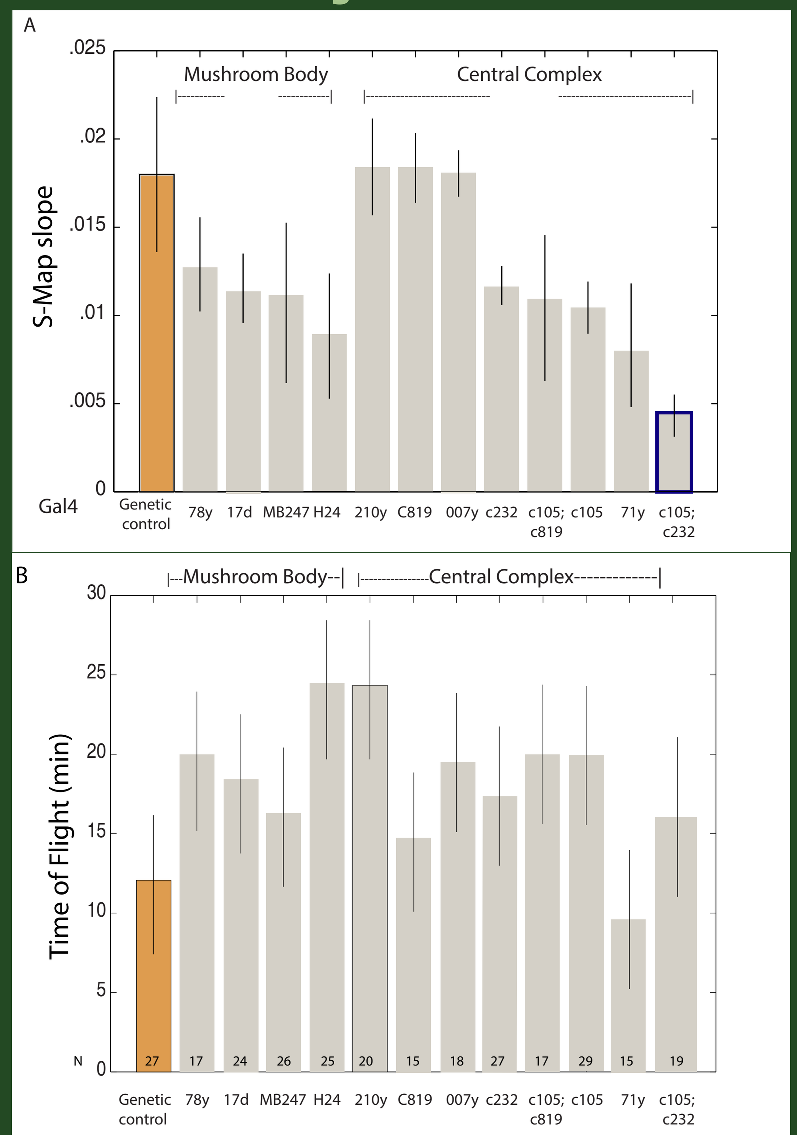


Fig. 2 A - Average slope of S-Map results from candidate fly lines expressing tetanus toxin light chain in various regions of the fly brain using the Gal4-UAS system. The slope of the S-Map results is calculated by a least square linear regression method.

B - Average time of flight in minutes. N - number of flies. Error bars represent standard error of the mean throughout.

4. Quantifying the randomness in candidate line ISIs

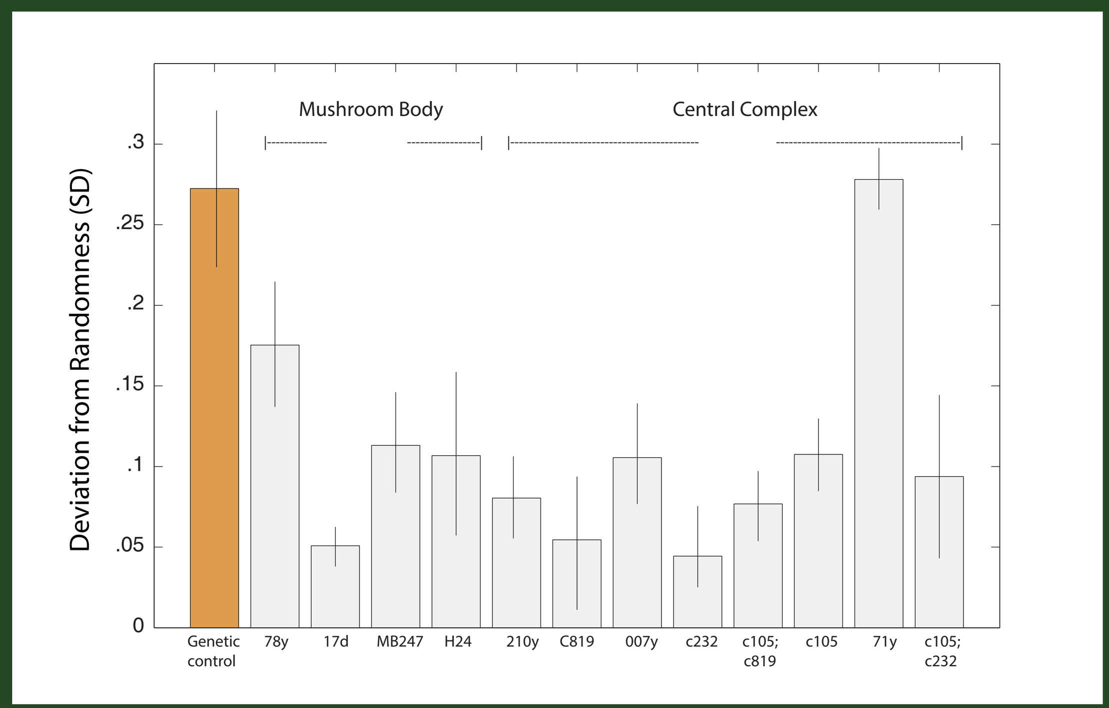


Fig. 3 Standard deviation from randomness (0 as ideal randomness) using Geometric Random Inner Products(GRIP) analysis of the ISI sequences.

5. Torque spike frequency

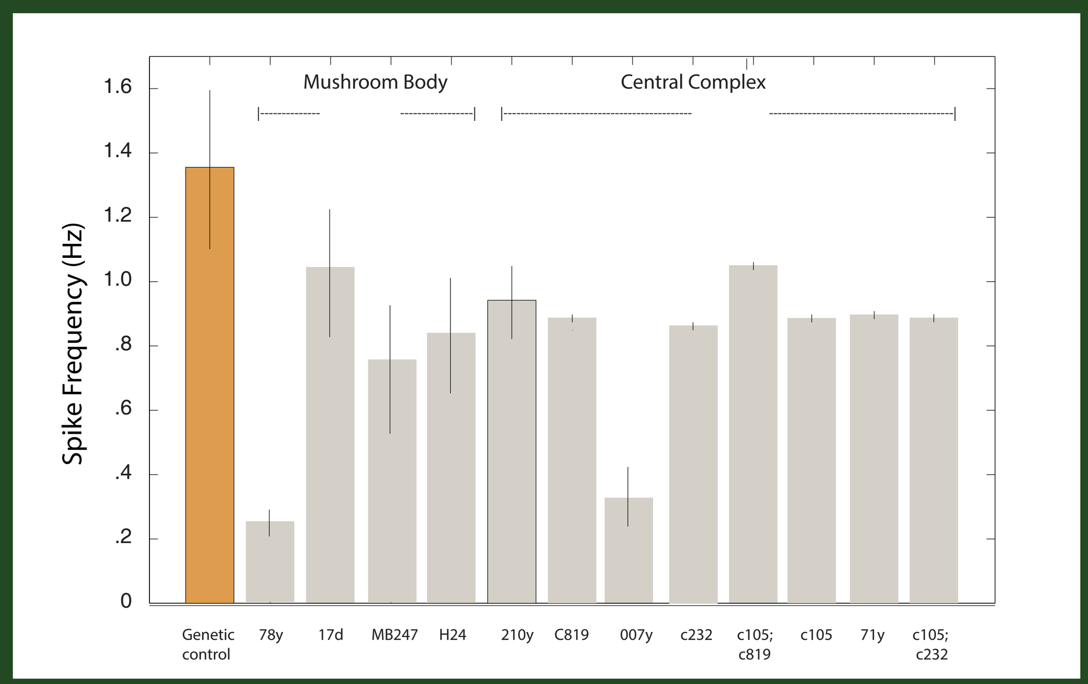


Fig. 4 The frequency with which torque spikes are produced during the experiments varies widely between candidate lines. However, the lines with the lowest average S-Map slope are not the same lines as those with the lowest spike frequency.

6. No oscillatory components in spontaneous fly turning behavior

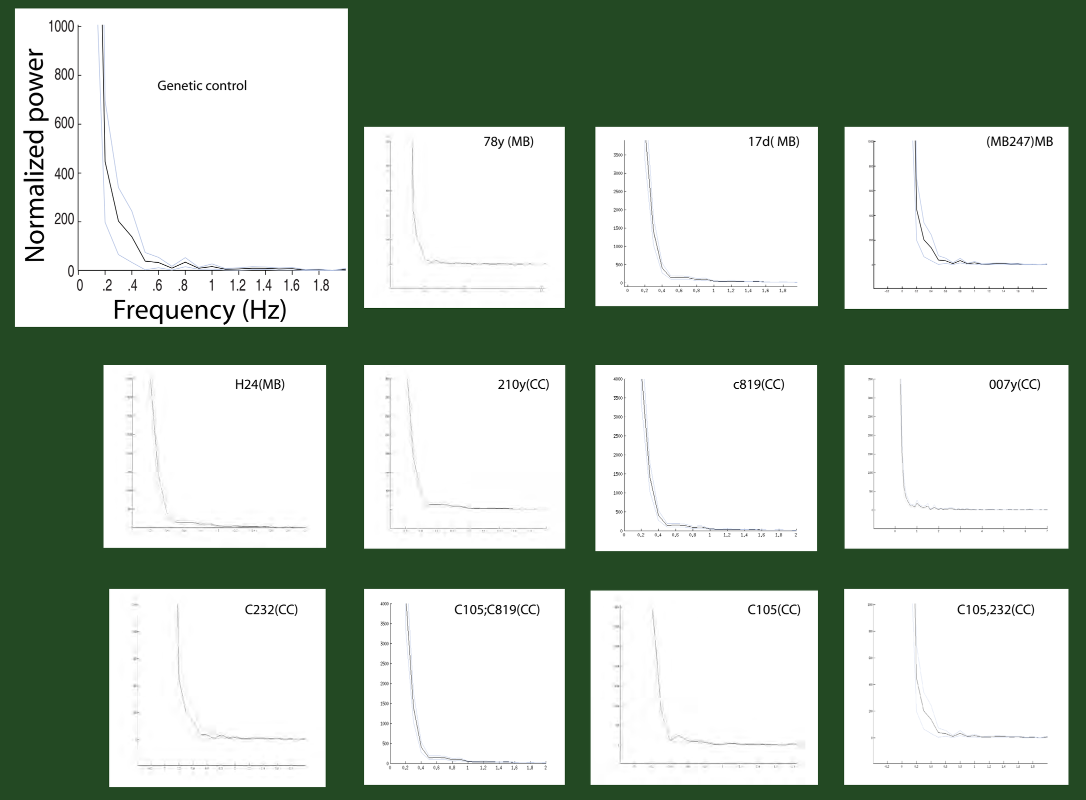


Fig. 5 Power spectra for control and candiate lines, calculated from raw yaw torque data. None of the flight traces show any obvious evidence of oscillatory behaviors.
CC-Central complex,MB-Mushroom body

7. Fano Factor analysis of torque spike variability

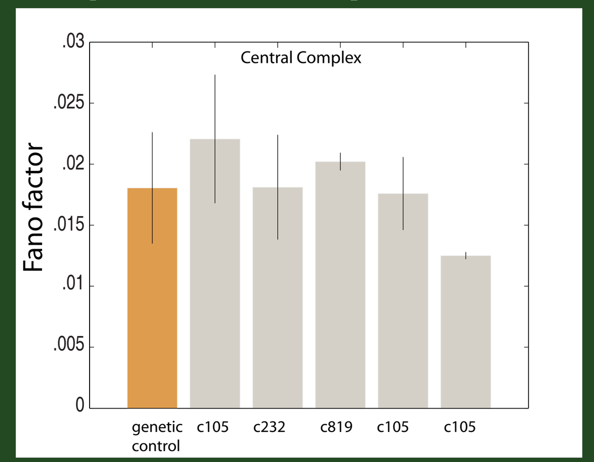


Fig. 6 The Fano factor (FF) is quantified by the ratio of the variance to mean spike count. The FF approaches 1 if the data is poisson distributed. The spike count is collected in 50s windows over the entire trace and the FF is calculated for each fly.

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