Supplemental Information

Movie 1: SOARS denoised ratio, estimated Ca^{2+} concentration and estimated firing rates as a function of time during a one-hour recording of PTZ induced seizure activity in a 7dpf larval zebrafish expressing the *cameleon* Ca^{2+} indicator in all neurons. Left panel: ratio; middle panel: $[Ca^{2+}]$; right panel: firing rate. The timestamp is given in seconds. Note that the event in Fig. 2 begins at frame 3035.

Movie 2: Estimated and NMF decomposition of the firing rate during a one-hour recording of PTZ induced seizure activity in a 7dpf larval zebrafish expressing the *cameleon* Ca^{2+} indicator in all neurons. Left panel: estimated firing rate; right panel: NMF decomposition of firing rate. Putative neuronal populations derived from the NMF are each depicted with a different color. 25 non-negative factors were used in this movie. Brightness of all factors was uniformly increased for ease of visualization (causing the NMF background in the right panel to look slightly higher than that of the firing rate in the left panel). This increase in brightness was for visualization purposes only and did not affect our statistical analysis in any way. The timestamp is given in seconds. Note that the event in Fig. 3 begins at frame 2380.

Computing Firing Rates from Calcium Time Series

Assuming that that all intracellular Ca^{2+} release is due to action potentials, the dynamics of intracellular Calcium concentration can be described by a first order differential equation:

$$\tau \frac{dc}{dt} = -c + \alpha \sum_i \delta\left(t - t_i\right)$$

where *c(t)* is the intracellular Calcium concentration at time, *t*, α is the Calcium release per action potential, the t_i's denote spike times, and $\delta(\ )$ is the Dirac delta function. Rearranging and putting all Calcium concentrations on the left-hand side, we have

$$\frac{dc}{dt} + \frac{c}{\tau} = \frac{\alpha}{\tau} \sum_i \delta\left(t - t_i\right)$$

After multiplying both sides by $e^{t/\tau}$ (to make the left-hand side a perfect differential) and integrating from $t=0$ to $t=\Delta t$, we get

$$\int_0^{\Delta t} e^{t/\tau} \left(dc + \frac{c}{\tau} dt \right) = \frac{\alpha}{\tau} \int_0^{\Delta t} \sum_i \delta\left(t - t_i\right) e^{t/\tau} dt$$

$$c\left(\Delta t\right) e^{\Delta t/\tau} - c\left(0\right) = \frac{\alpha}{\tau} \sum_i e^{t_i/\tau}$$

Now assuming that the firing is periodic during this time interval, the right-hand side can be easily summed to obtain

$$c(\Delta t)e^{\Delta t/\tau} - c(0) = \frac{\alpha}{\tau}\frac{1-e^{\Delta t/\tau}}{1-e^{1/m\tau}}$$

where m is the firing rate during this time interval. Solving for m, we get that the firing rate, during this zero-th time interval, is given by

$$m(0) = \frac{1}{\tau}\left[\ln\left(1-\frac{\alpha e^{-\frac{\Delta t}{\tau}}\left(1-e^{\frac{\Delta t}{\tau}}\right)}{c(\Delta t)-c(0)e^{-\frac{\Delta t}{\tau}}}\right)\right]^{-1}$$

And generalizing to all time intervals, we finally obtain

$$m(t) = \frac{1}{\tau}\left[\ln\left(1-\frac{\alpha e^{-\frac{\Delta t}{\tau}}\left(1-e^{\frac{\Delta t}{\tau}}\right)}{c(t+\Delta t)-c(t)e^{-\frac{\Delta t}{\tau}}}\right)\right]^{-1}.$$