# First analysis of Emmett' data

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## 1 Introduction

Here I use svGPFA (Duncker and Sahani, 2018) to explore the low dimensional structure of Emmett's switching-task recordings.

## 2 Methods

### 2.1 Data

I epoched the recordings from 0.2 seconds before to mouse entered the first port (port 2) to 0.2 seconds after it exited the last port (port 7).

I only used trial that were shorter than five seconds (257 trials out of 400 trial with correct sequences).

I only used neurons with a firing rater larger than 0.1 spikes/sec (230 out of 400 neurons).

### 2.2 svGPFA model

The svGPFA model estimates $K$ latent variables in the form of Gaussian processes:

$$x_k^{(r)}(t) \sim GP(\mu_k(t), \kappa_k(t, t')) \quad k = 1, \ldots, K$$

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I concatenate the latent variables $x_k^{(r)}(t)$ into a latent vector $\mathbf{x}^{(r)}(t)$:

$$\mathbf{x}^{(r)}(t) = \begin{bmatrix} x_1^{(r)}(t) \\ \vdots \\ x_K^{(r)}(t) \end{bmatrix} \tag{1}$$

The latent variables are combined linearly to produced the log pre-intensity, $\mathbf{h}^{(r)}(t) = [h_1^{(r)}(t), \ldots, h_N^{(r)}(t)]^\intercal$, where $h_n^{(r)}(t)$ is the log pre-intensity of neuron $n$ and trial $r$, for a total of $N$ neurons:

$$\mathbf{h}^{(r)}(t) = C\mathbf{x}^{(r)}(t) + \mathbf{d} \tag{2}$$

The log pre-intensity of neuron $n$ and trial $r$ is exponentiated to produce the conditional intensity function of neuron $n$ and trial $r$:

$$\lambda_n^{(r)}(t) = \exp(h_n^{(r)}(t)) \tag{3}$$

which can be interpreted as the instantaneous firing rate of neuron $n$ and trial $r$ at time $t$.

The conditional intensity function of neuron $n$ in trial $r$ is used to calculate the probability of spikes $\{t_{i,n}\}_{i=1}^{\Phi(n,r)}$ in a trial $r$ of length $\tau$:

$$P(\{t_{i,n}\}_{i=1}^{\Phi(n,r)} | \lambda_n^{(r)}(t)) = \exp\left(-\int_0^\tau \lambda_n^{(r)}(t)dt\right) \prod_{i=1}^{\Phi(n,r)} \lambda_n^{(r)}(t_{i,n})$$

# 3 Results

I arbitrarily set to 10 the number of latent variables ($K$ in Eq. 1 of Duncker and Sahani, 2018)) of the svGPFA model. Figures 3-12 plot the orthonormalized latents for all trials. Figure 13 shows a scatter plot of orthonormalized latents 0, 1 and 2. Figures 14-29 plot intensity functions (Eq. 3), for all trials, of different neurons. Figure 31 plot the left singular vectors of the matrix $C$ (Eq. 2), corresponding to the orthonormalized latents, and the offset vector $d$. Figure 32 displays the estimated lenghtscale parameters of the squared exponential kernels of all latents.

# 4 Conclusions

The intensity functions if Figures 14-29 show diverse tunning of single cells. The majority of them fire more when the mouse enters the reward port 7 (e.g., neurons 1 (Figure 15), 2 (Figure 16), 4 (Figure 18), 6 (Figure 19), 7 (Figure 20), 17 (Figure 30)). Other neurons fire more when the mouse enters other ports (e.g., neurons 0 (Figure 14), 15 (Figure 28), 16 (Figure 29) fire more around port 1, neuron 3 (Figure 17) around por 3, neuron 12 (Figure 25) around porr 2).

Despite this diversity at the single cell level, the first three orthonormalized latents show a pattern at the population level (Figure 13). For most trials, there appears to be an extreme point around the time where the mouse pokes in a port.

In addition, in Fig. 13 trials are sorted systematically, possibly indicating some type of learning, or drift in neural activity.

# References

Duncker, L. and Sahani, M. (2018). Temporal alignment and latent gaussian process factor inference in population spike trains. In *Advances in Neural Information Processing Systems*, pages 10445–10455.

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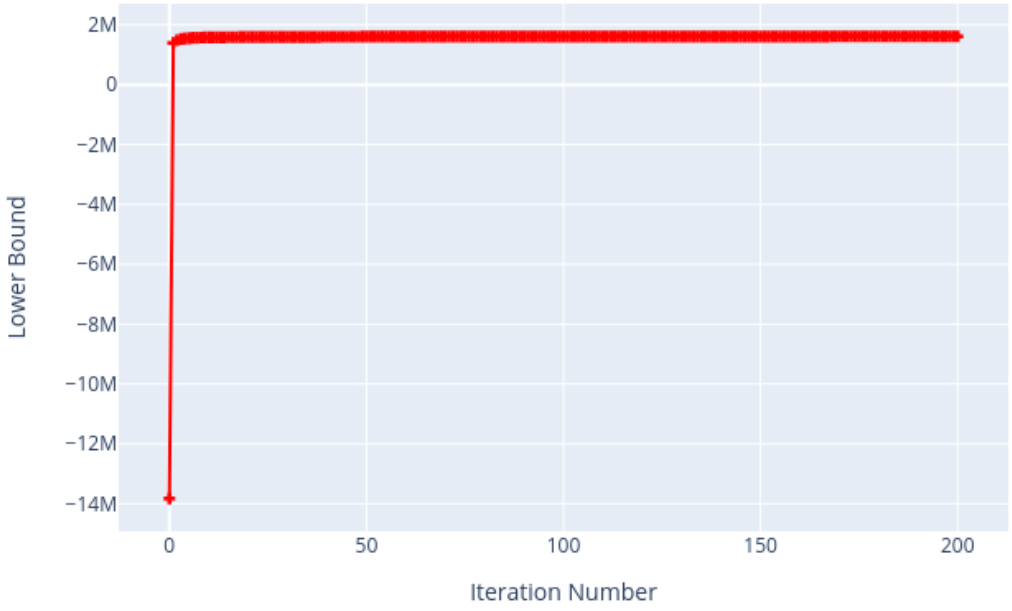


Figure 1: Lower bound vs iteration number. Click on the image to access its interactive version.

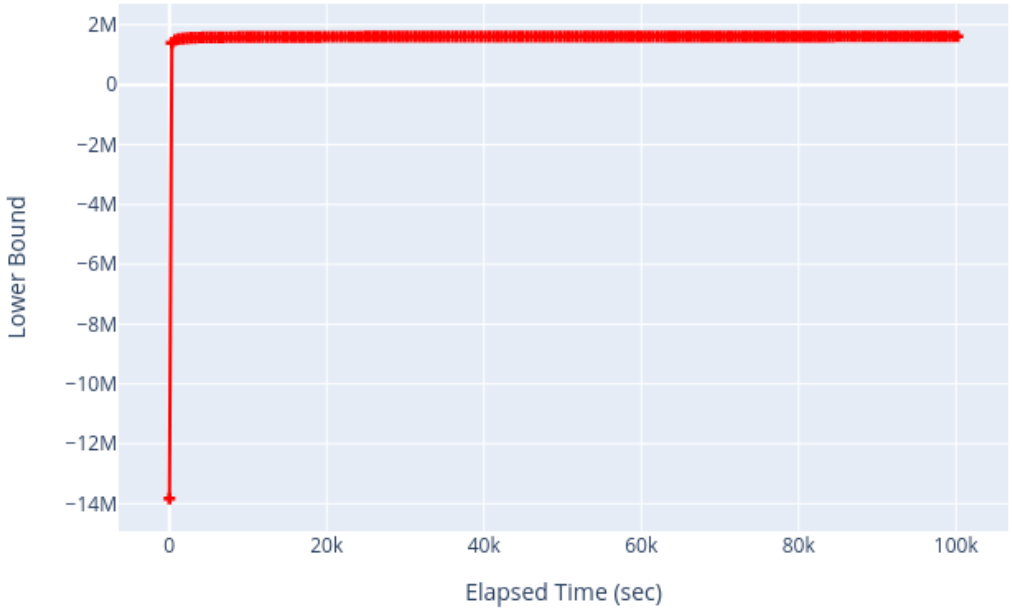


Figure 2: Lower bound vs elapsed time. Click on the image to access its interactive version.

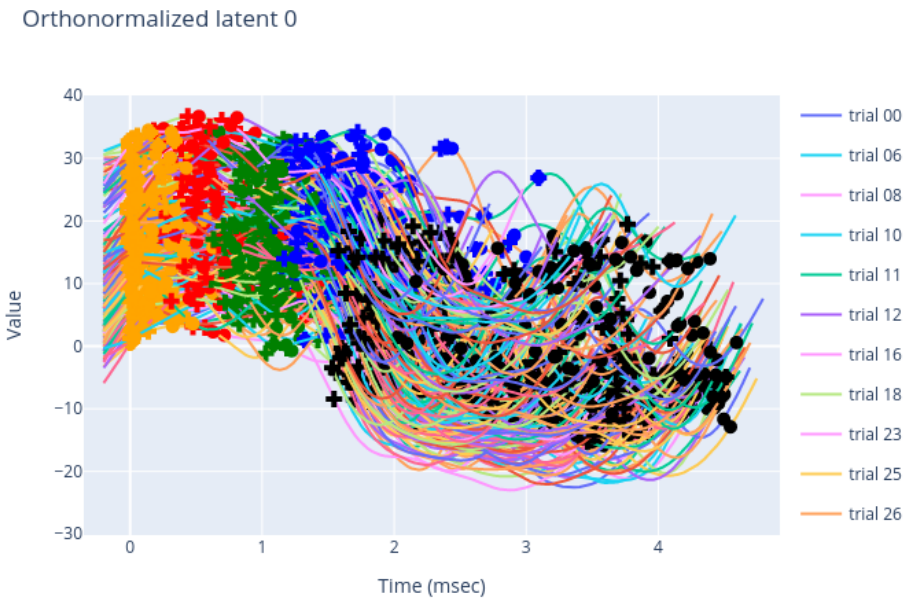


Figure 3: Orthonormalized latent 0. Orange, red, green, blue and black markers correspond to ports 2, 1, 6, 3 and 7, respectively. Crosses and circles correspond to poke in and out, respectively.

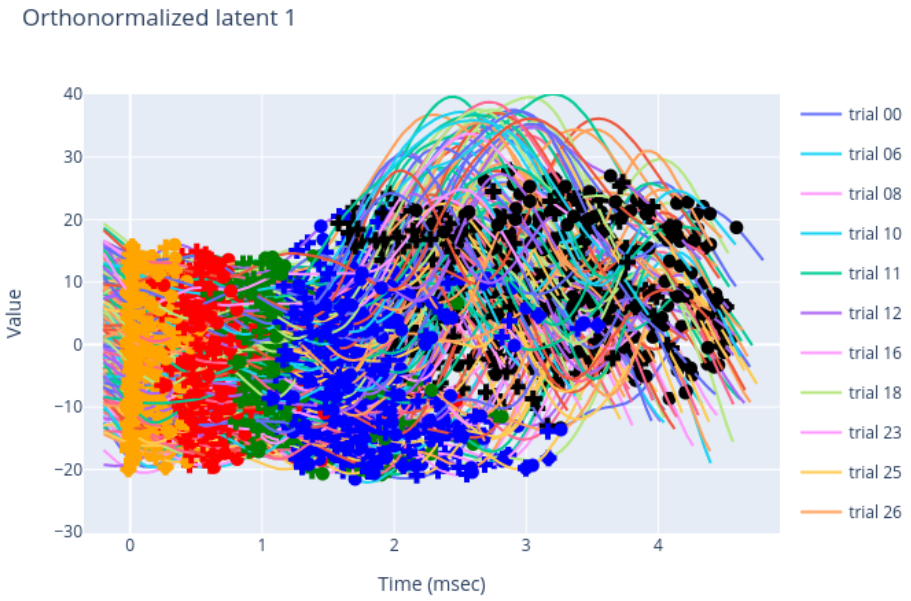


Figure 4: Orthonormalized latent 1. Same format as in Figure 3. Click on the image to access its interactive version.

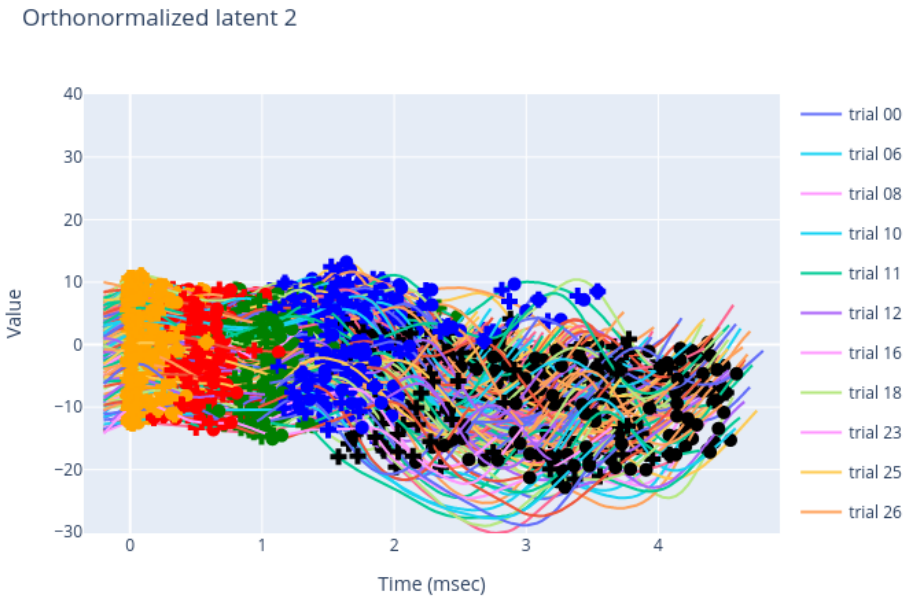


Figure 5: Orthonormalized latent 2. Same format as in Figure 3. Click on the image to access its interactive version.

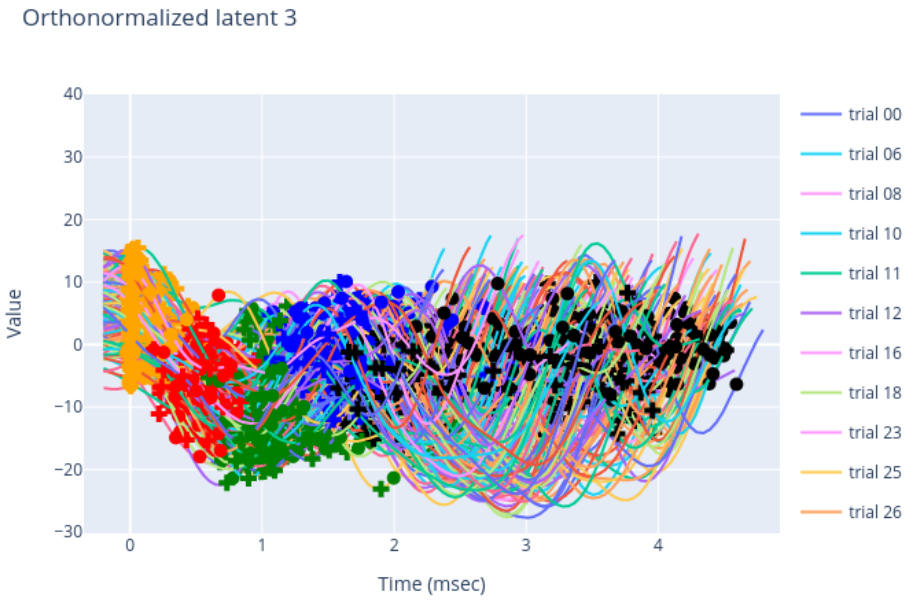


Figure 6: Orthonormalized latent 3. Same format as in Figure 3. Click on the image to access its interactive version.

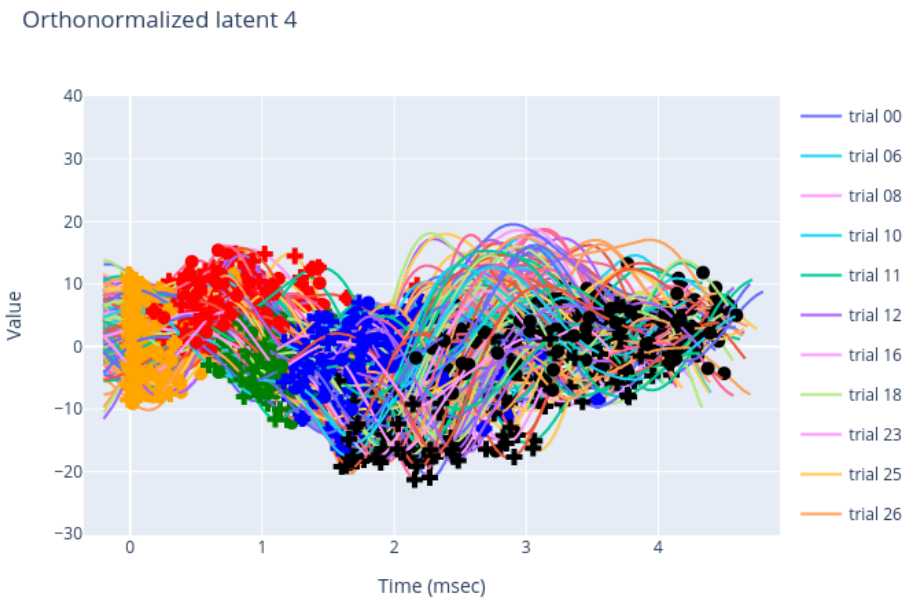


Figure 7: Orthonormalized latent 4. Same format as in Figure 3. Click on the image to access its interactive version.

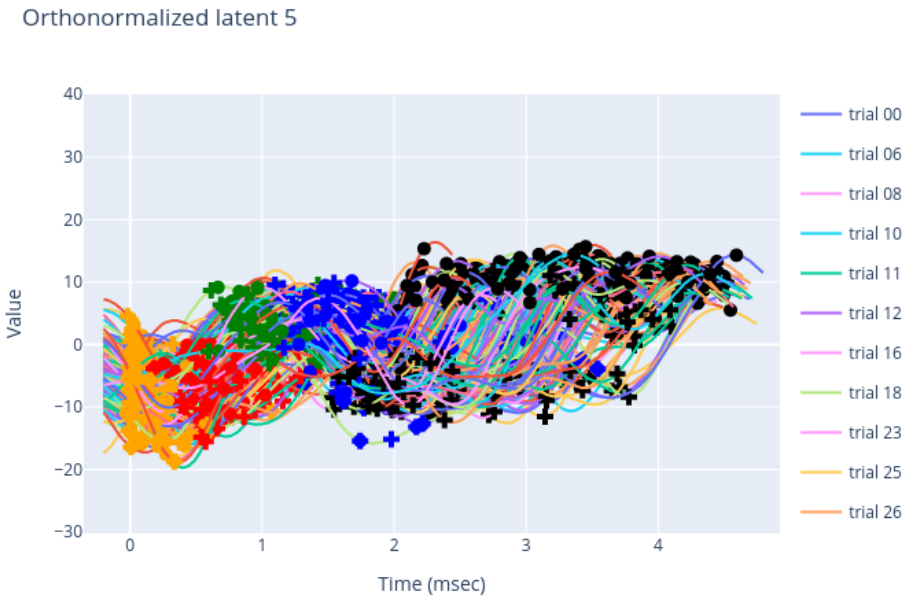


Figure 8: Orthonormalized latent 5. Same format as in Figure 3. Click on the image to access its interactive version.

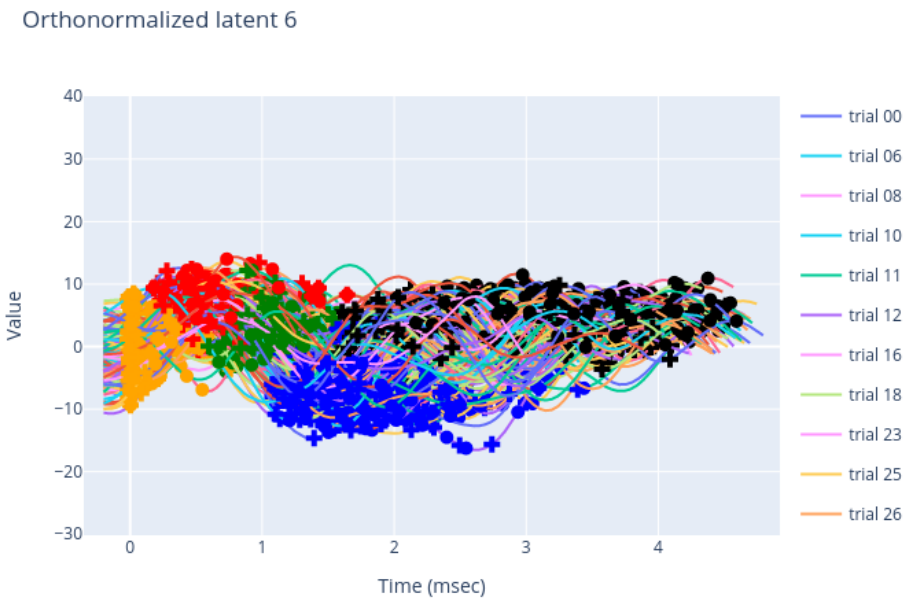


Figure 9: Orthonormalized latent 6. Same format as in Figure 3. Click on the image to access its interactive version.

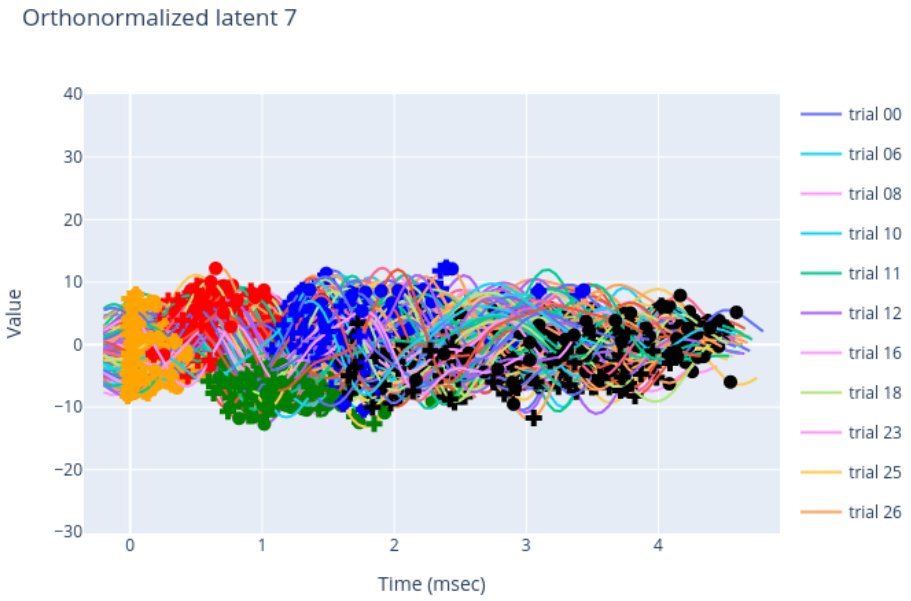


Figure 10: Orthonormalized latent 7. Same format as in Figure 3. Click on the image to access its interactive version.

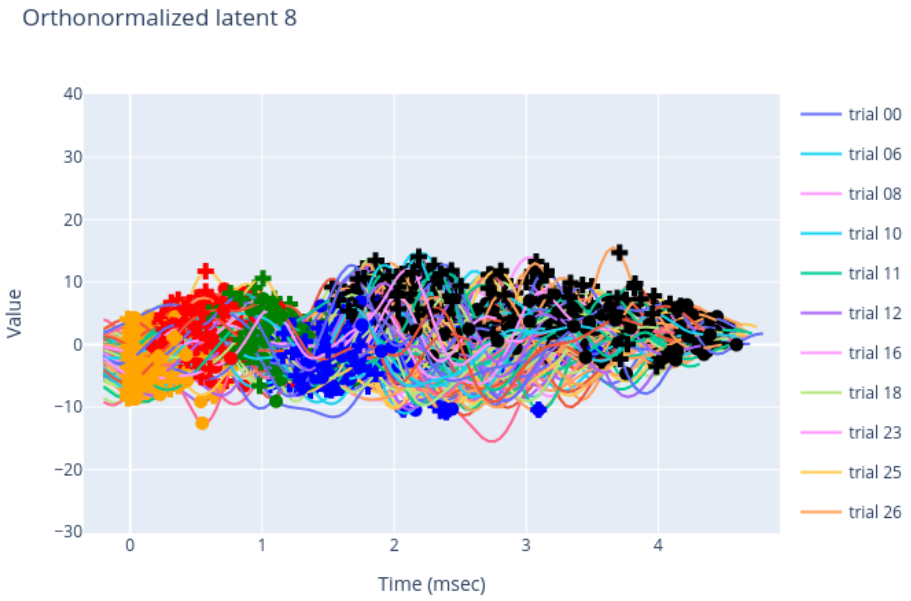


Figure 11: Orthonormalized latent 8. Same format as in Figure 3. Click on the image to access its interactive version.

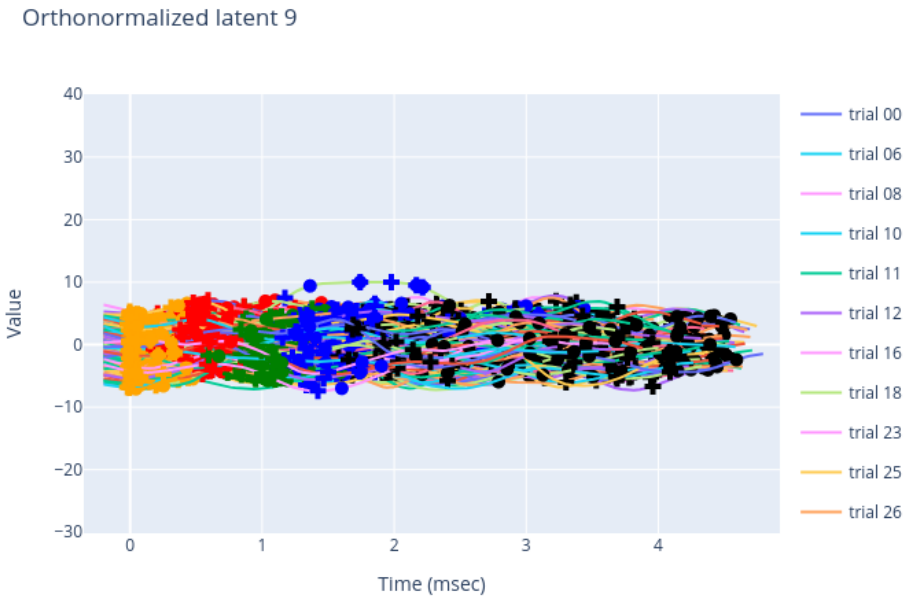


Figure 12: Orthonormalized latent 9. Same format as in Figure 3. Click on the image to access its interactive version.

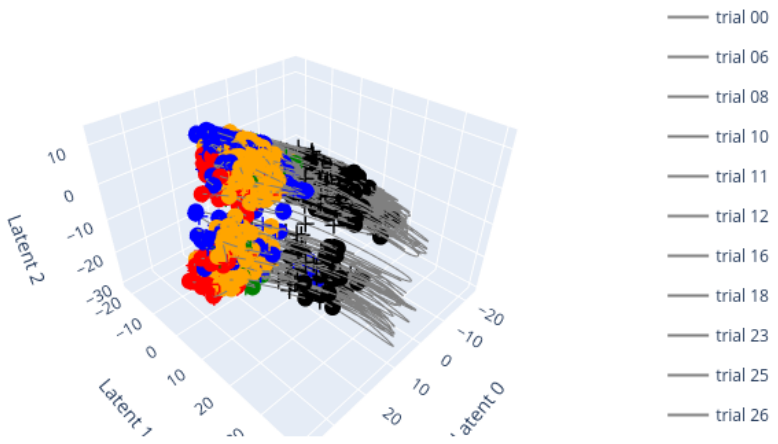


Figure 13: Scatter plot of orthonormalized latents 0, 1 and 2. Same format as in Figure 3. Click on the image to access its interactive version.

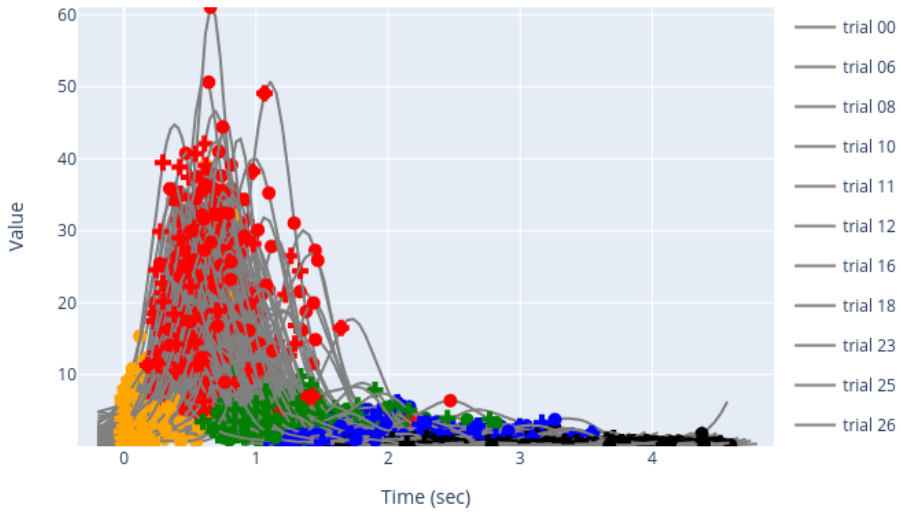


Figure 14: Intensity function for neuron $n = 0$ ($\lambda_n(t)$, Eq. 3). Same format as in Figure 3. Click on the image to access its interactive version.

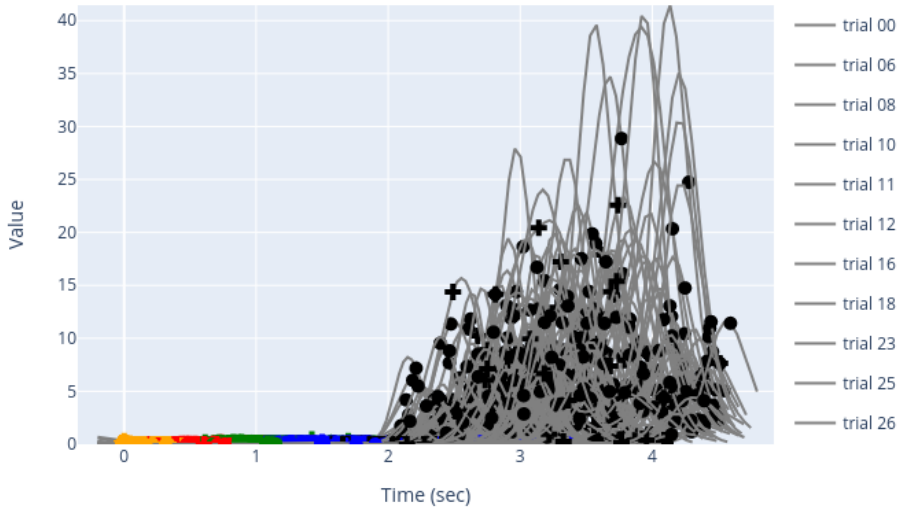


Figure 15: Intensity function for neuron $n = 1$ ($\lambda_n(t)$, Eq. 3). Same format as in Figure 3. Click on the image to access its interactive version.

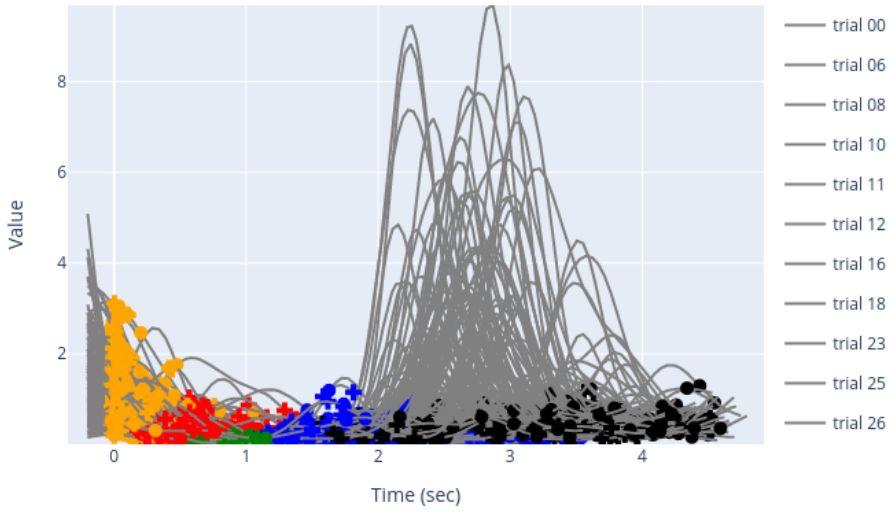


Figure 16: Intensity function for neuron $n = 2$ ($\lambda_n(t)$, Eq. 3). Same format as in Figure 3. Click on the image to access its interactive version.

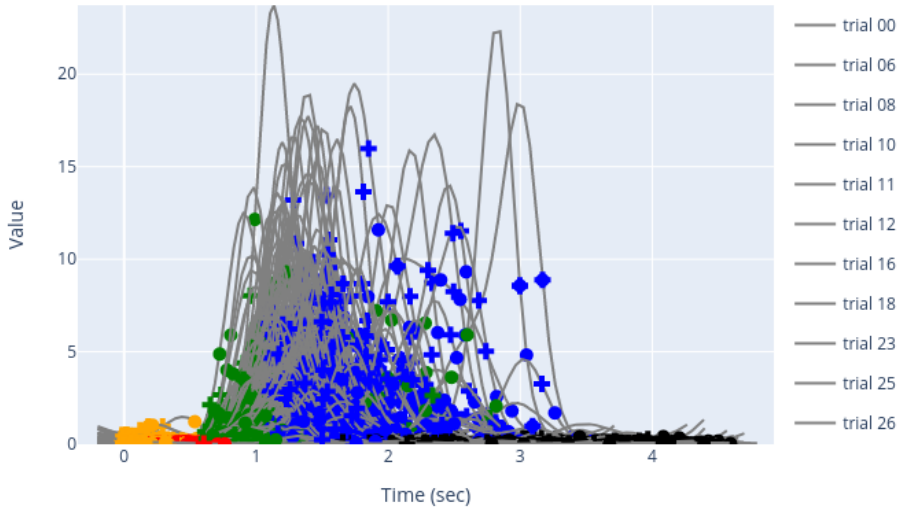


Figure 17: Intensity function for neuron $n = 3$ ($\lambda_n(t)$, Eq. 3). Same format as in Figure 3. Click on the image to access its interactive version.

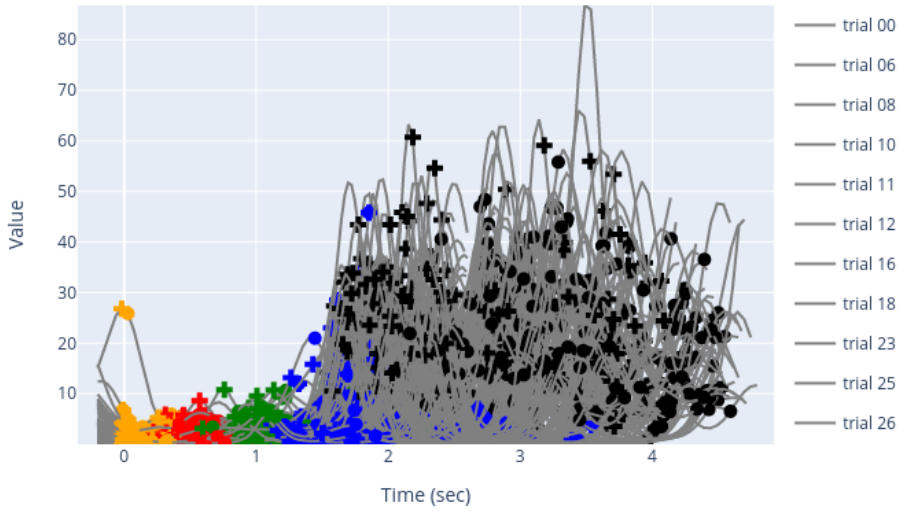


Figure 18: Intensity function for neuron $n = 4$ ($\lambda_n(t)$, Eq. 3). Same format as in Figure 3. Click on the image to access its interactive version.

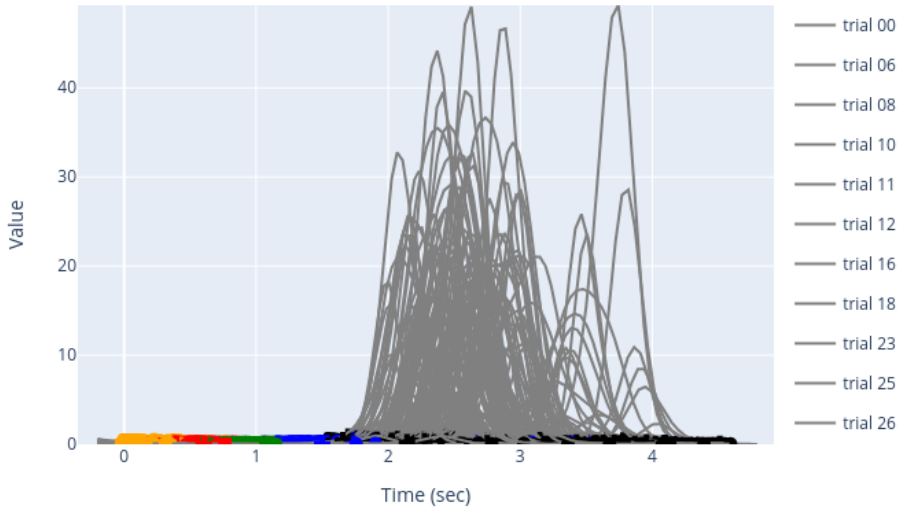


Figure 19: Intensity function for neuron $n = 6$ ($\lambda_n(t)$, Eq. 3). Same format as in Figure 3. Click on the image to access its interactive version.

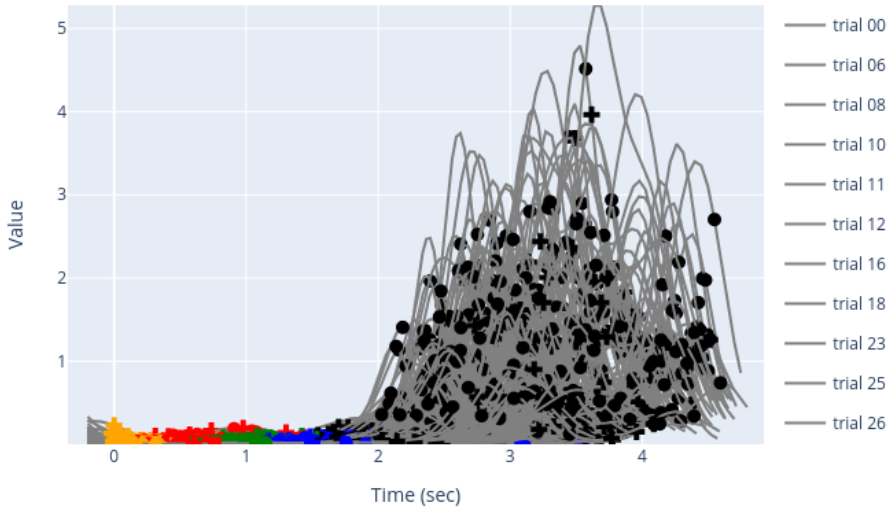


Figure 20: Intensity function for neuron $n = 7$ ($\lambda_n(t)$, Eq. 3). Same format as in Figure 3. Click on the image to access its interactive version.

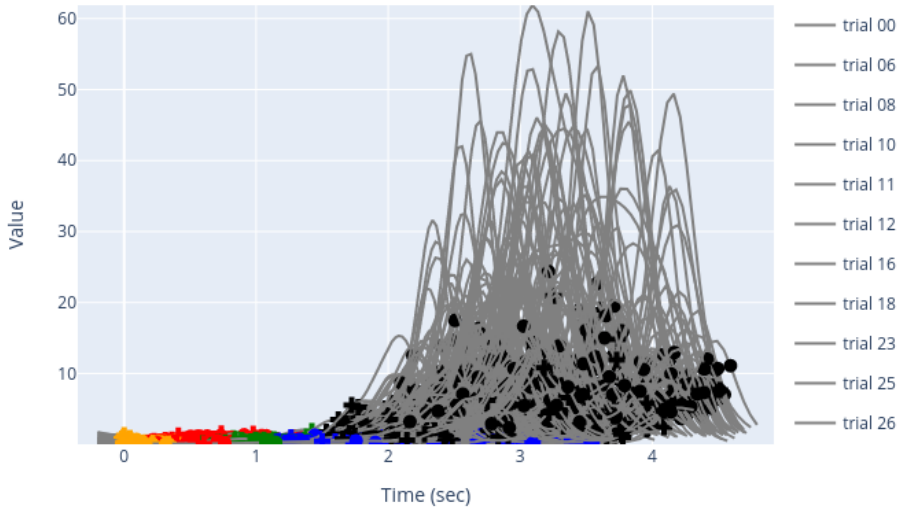


Figure 21: Intensity function for neuron $n = 8$ ($\lambda_n(t)$, Eq. 3). Same format as in Figure 3. Click on the image to access its interactive version.

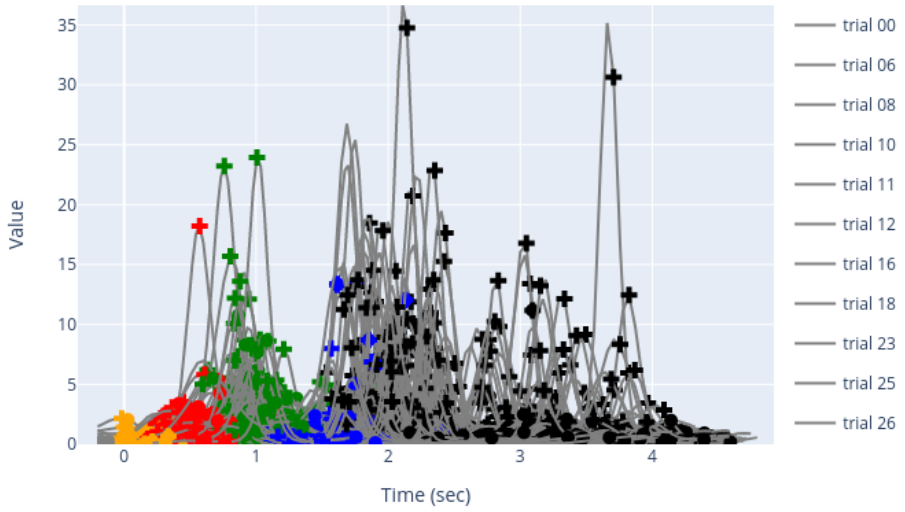


Figure 22: Intensity function for neuron $n = 9$ ($\lambda_n(t)$, Eq. 3). Same format as in Figure 3. Click on the image to access its interactive version.

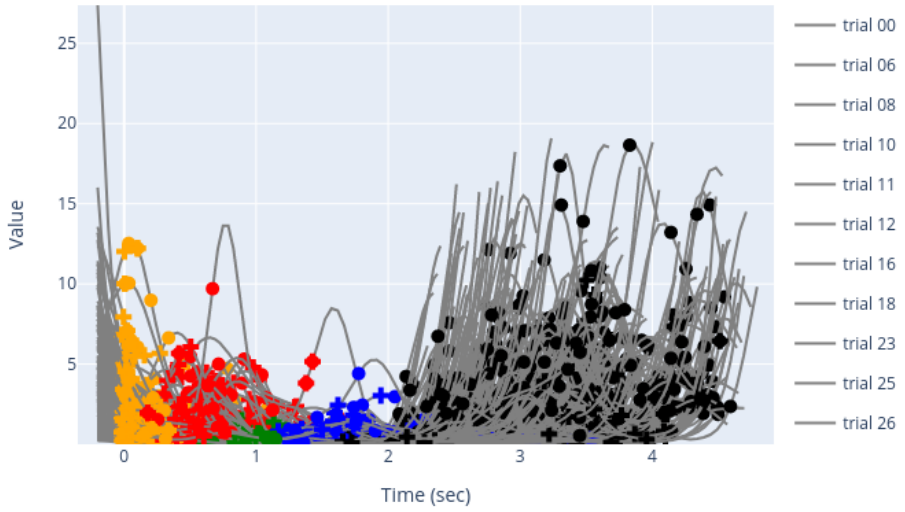


Figure 23: Intensity function for neuron 10. Same format as in Figure 3. Click on the image to access its interactive version.

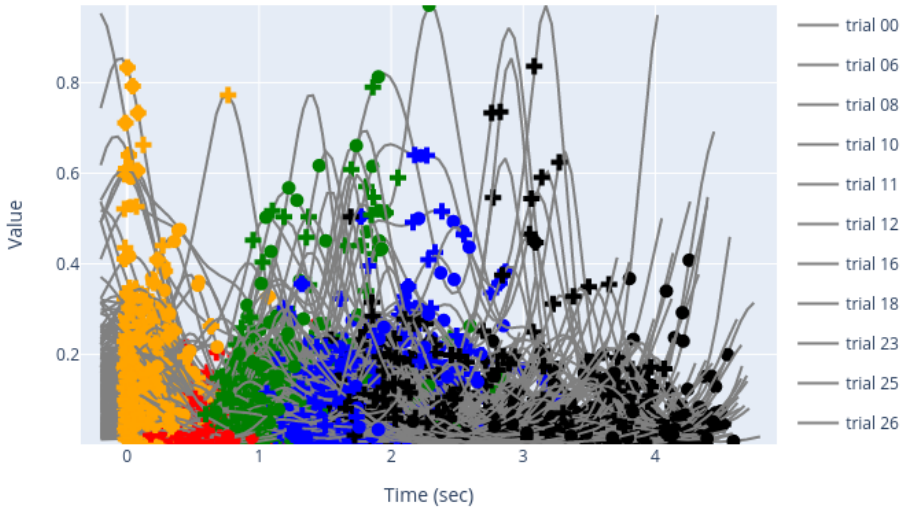


Figure 24: Intensity function for neuron 11. Same format as in Figure 3. Click on the image to access its interactive version.

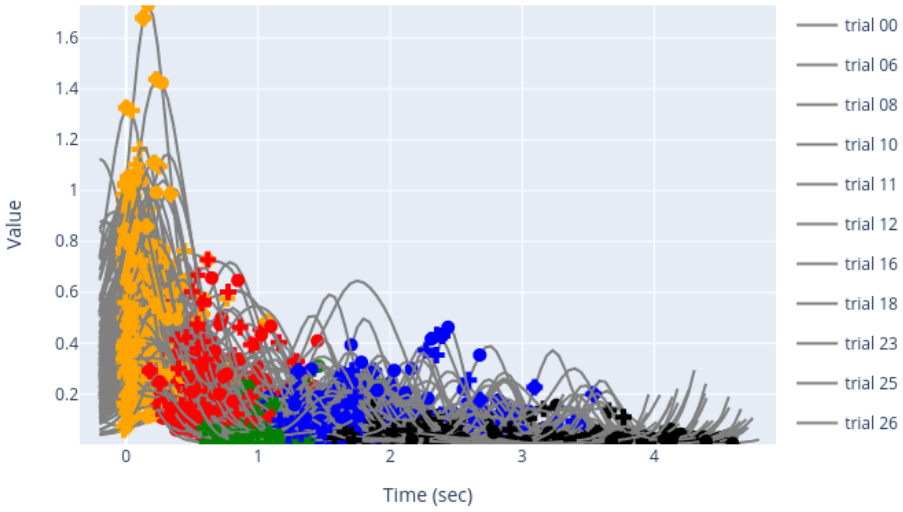


Figure 25: Intensity function for neuron 12. Same format as in Figure 3. Click on the image to access its interactive version.

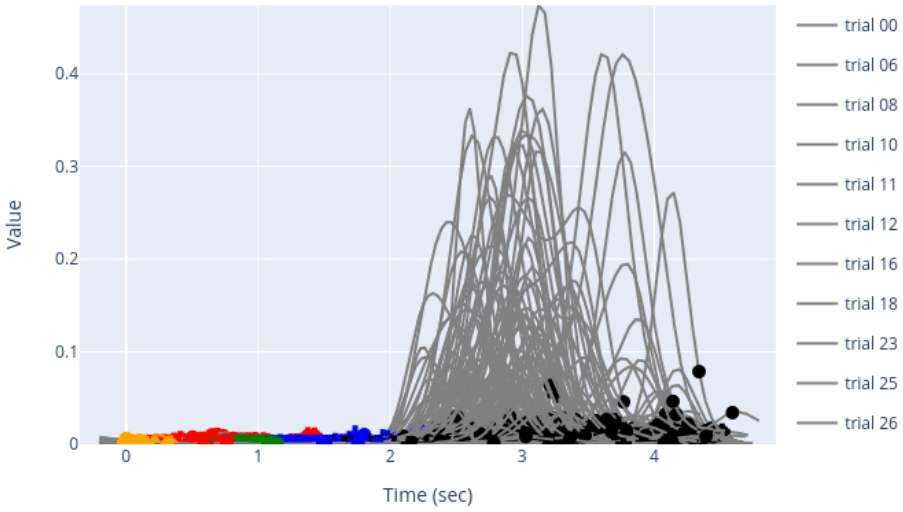


Figure 26: Intensity function for neuron 13. Same format as in Figure 3. Click on the image to access its interactive version.

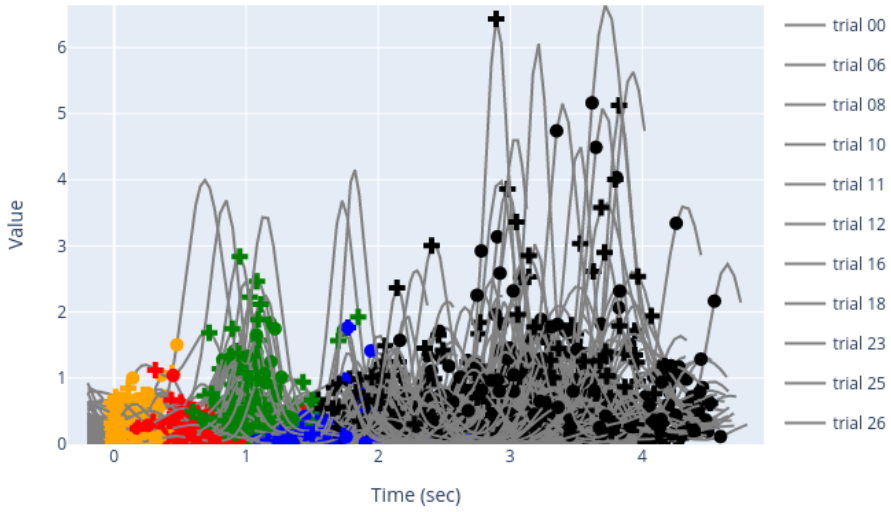


Figure 27: Intensity function for neuron 14. Same format as in Figure 3. Click on the image to access its interactive version.

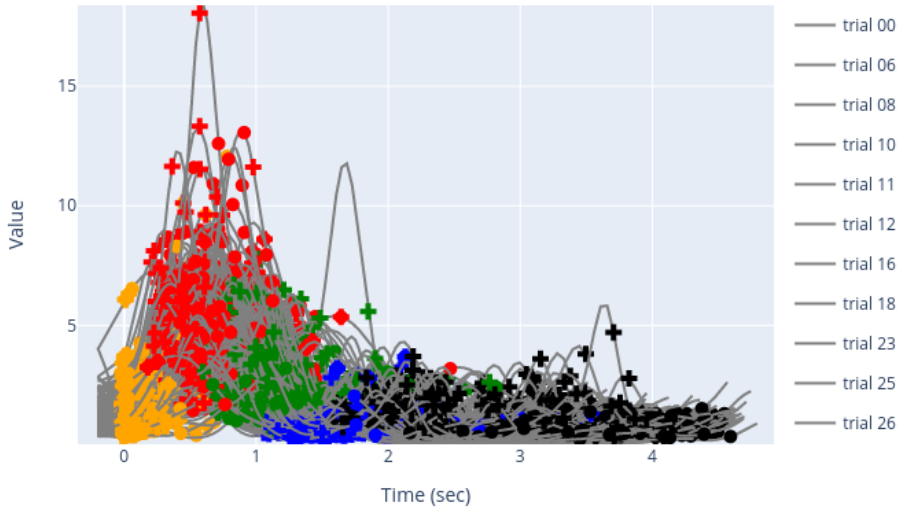


Figure 28: Intensity function for neuron 15. Same format as in Figure 3. Click on the image to access its interactive version.

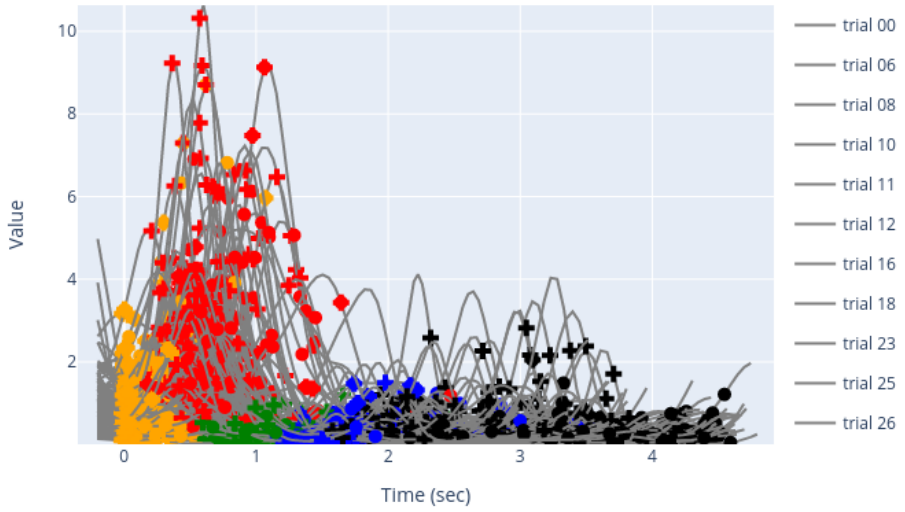


Figure 29: Intensity function for neuron 16. Same format as in Figure 3. Click on the image to access its interactive version.

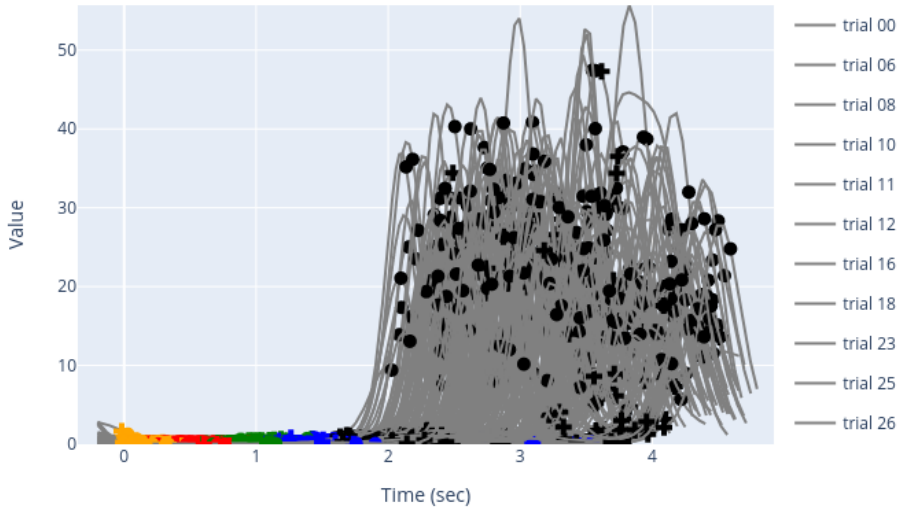


Figure 30: Intensity function for neuron 17. Same format as in Figure 3. Click on the image to access its interactive version.

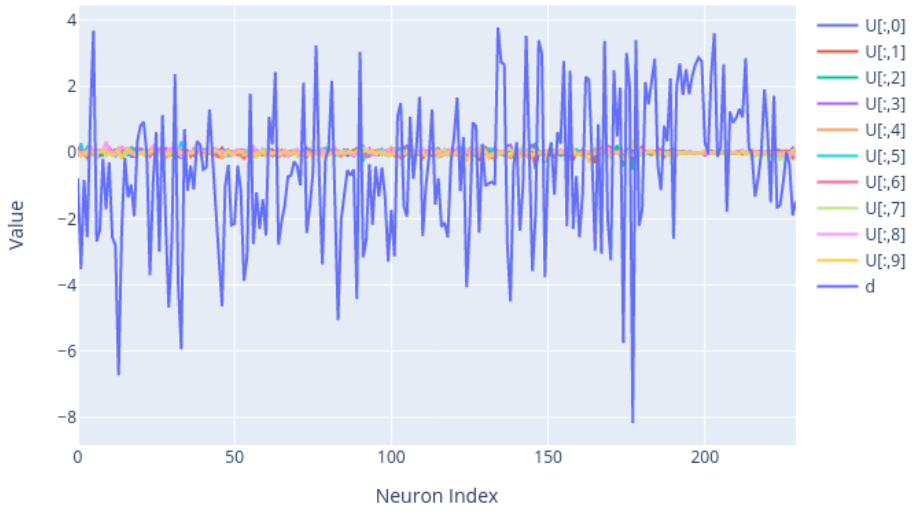


Figure 31: Left singular vectors of the matrix $C$ corresponding to the orthonormalized latents, and offset vector $\mathbf{d}$, (Eq. 2). Click on the image to access its interactive version.

Figure 32: Estimated lenghtscale parameters of the squared exponential kernels of all latents. Click on the image to access its interactive version.