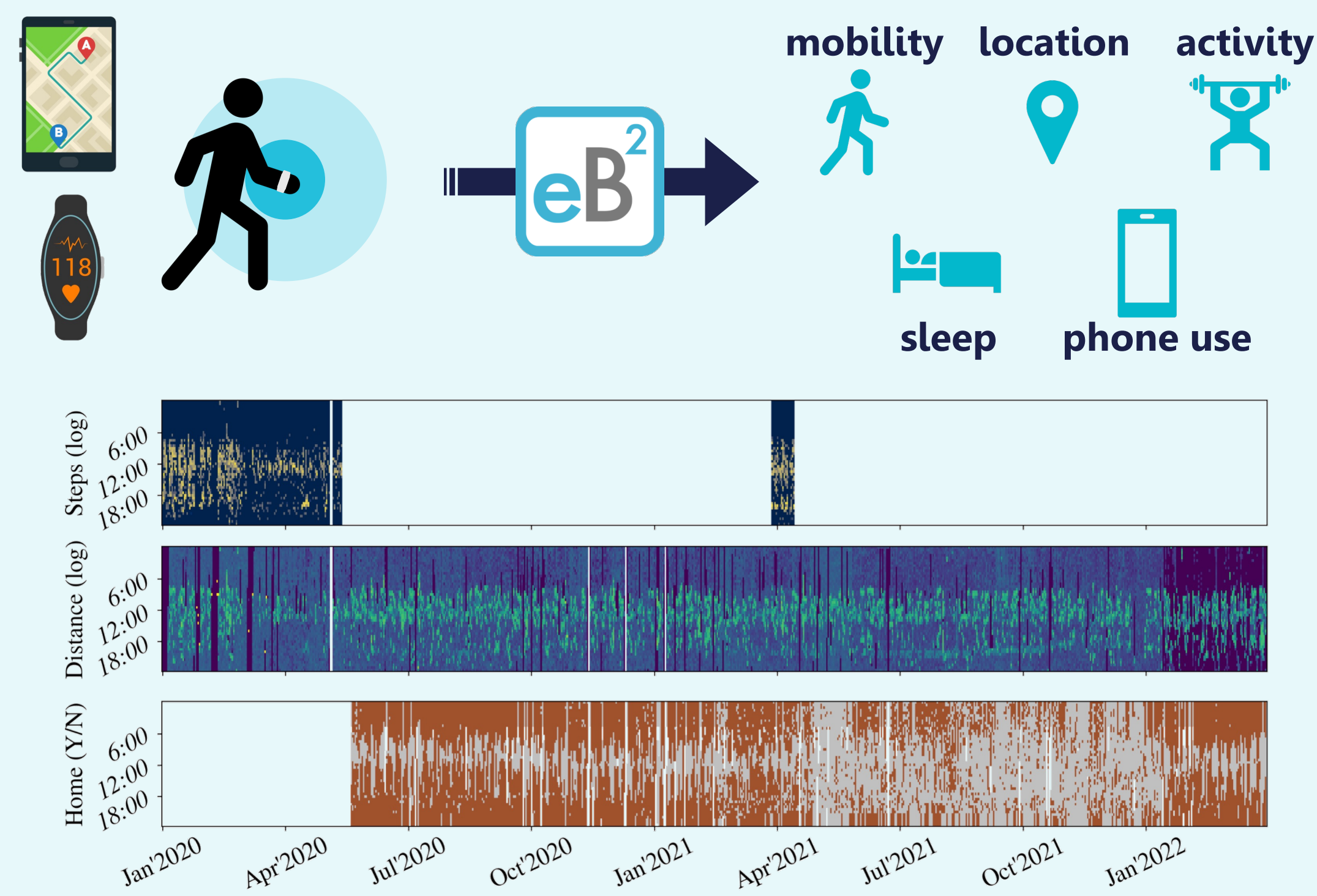


Representation Models for Human Behavior and Health

DATA

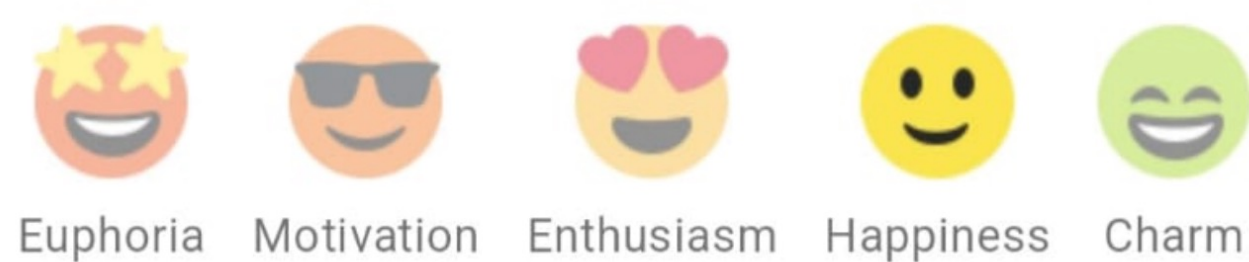
Behavior

digital phenotyping

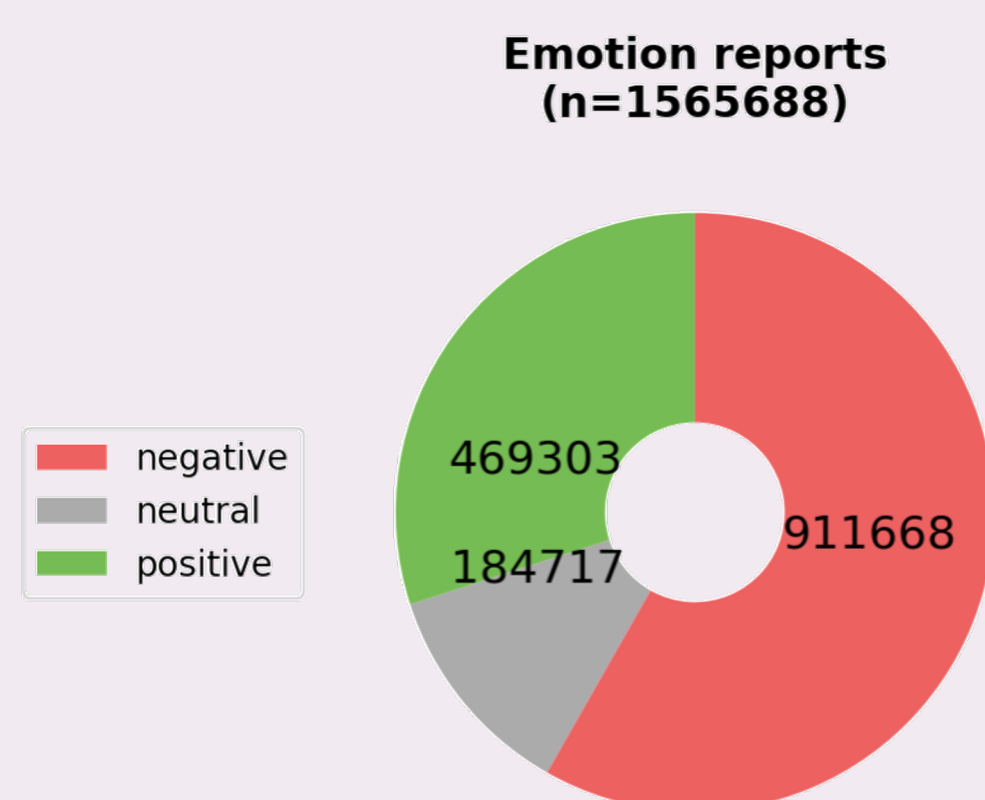


Self-reports

What are you feeling right now?



emotions notes, audio notes



Clinical records

static features

- demography
- diagnoses
- clinical scales

Basal features representing patient traits that do not change, or states

dynamic history

- hospitalizations
- suicidal crises
- medication and treatment

Event time series registered in an intermittent manner

METHODS

behavior profiling^[1]

- Heterogeneous mixture modeling (HetMM)**
Personalized probabilistic and discrete profiles trained on granular data
- Vector-quantized variational autoencoder (VQ-VAE)**
Encoder-decoder architecture, latent space composed of K discrete embeddings

complete likelihood

$$p(\mathbf{x}_t, \mathbf{z}_t = k) = p(\mathbf{x}_t | \phi_k^{(d)}) \prod_{k=1}^K p(\mathbf{z}_t = k) \prod_{d=1}^D p(\mathbf{x}_t^{(d)} | \phi_k^{(d)}) \mathbb{I}\{\mathbf{z}_t = k\}$$

loss function

$$\mathcal{L} = \log p(\mathbf{x} | \mathbf{z}_q(\mathbf{x})) + \|\text{sg}[\mathbf{z}_e(\mathbf{x})] - \mathbf{e}_k\|_2^2 + \beta \|\mathbf{z}_e(\mathbf{x}) - \text{sg}[\mathbf{e}_k]\|_2^2$$

reconstruction loss

codebook loss

commitment loss

event modeling

- Neural Hawkes process (NHP)**^[2]
A network learns Hawkes parameters from basal features, and the model survival function can be used as risk indicator

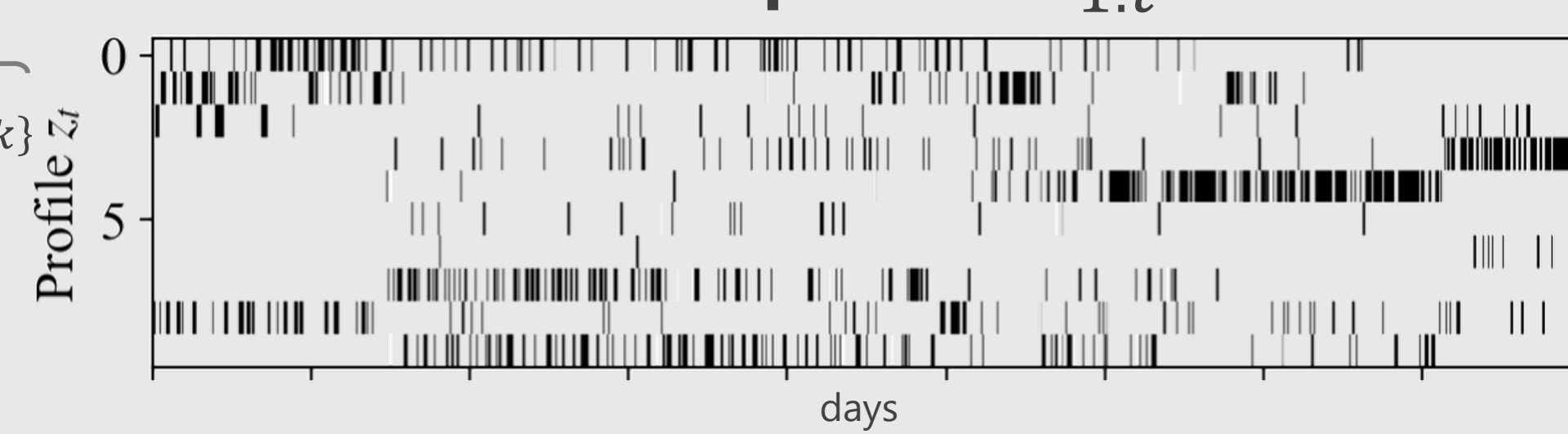
intensity function

$$\lambda(t) = \mu + \sum_{t_i < t} \alpha e^{-\delta(t-t_i)}$$

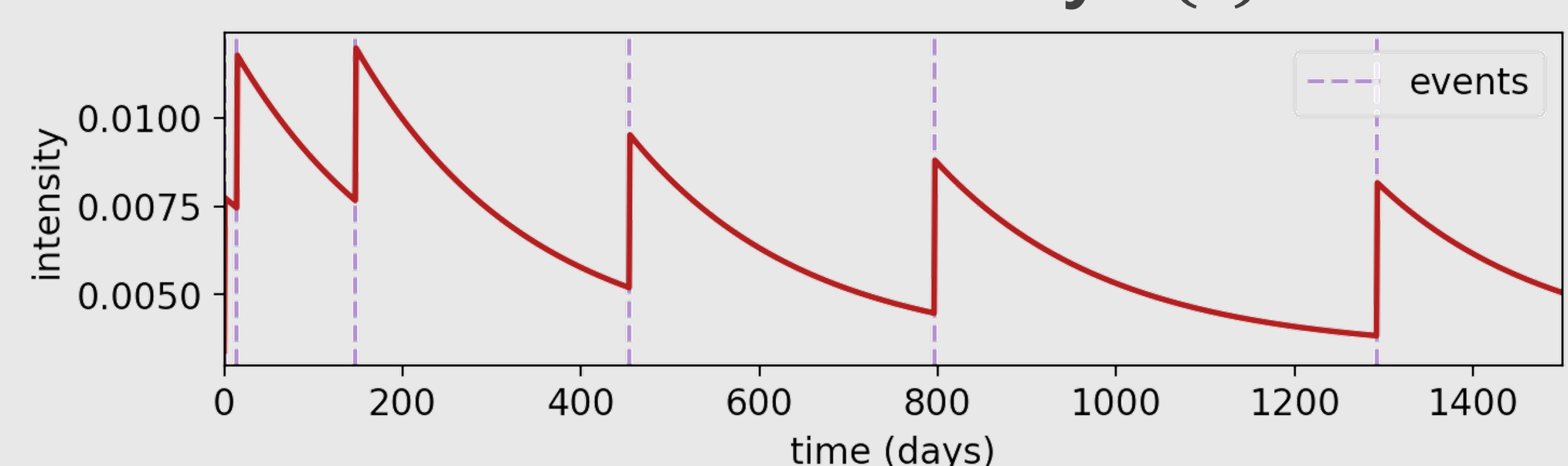
survival function

$$S(t) = e^{-\int_{t-w}^t \lambda(t) dt}$$

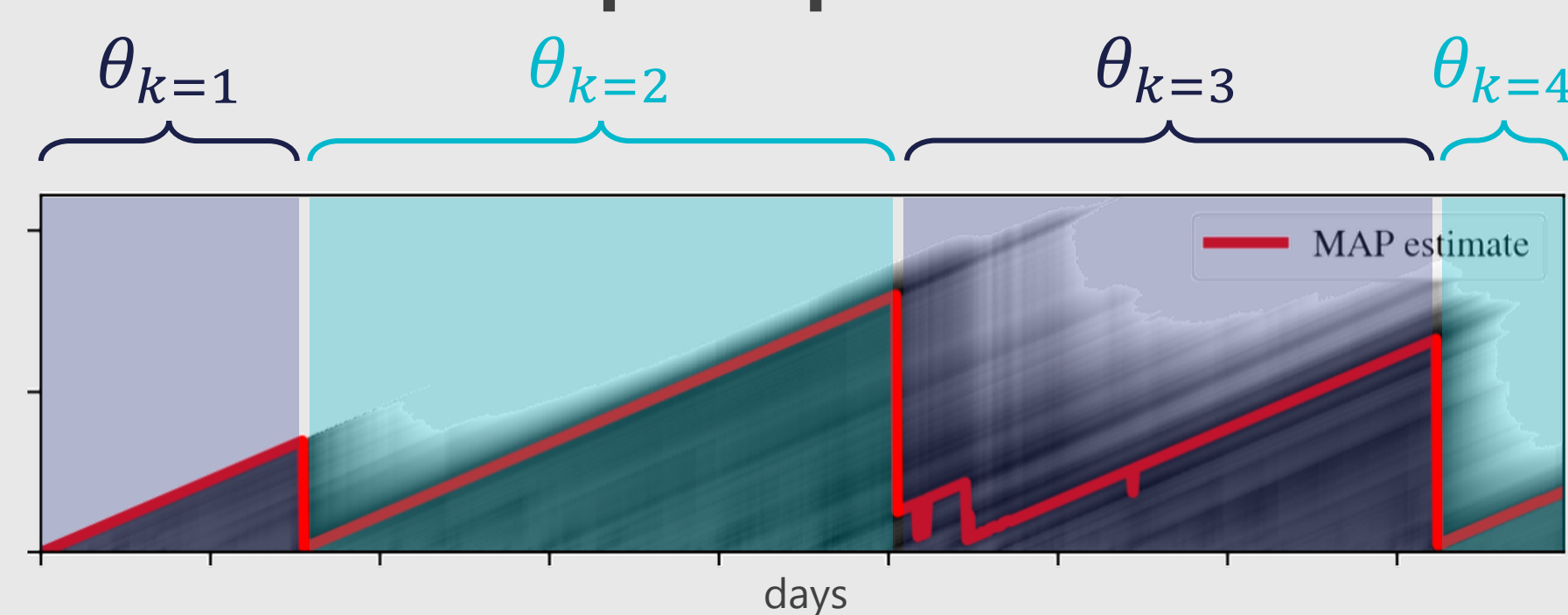
Latent profile $\mathbf{Z}_{1:t}$



Hawkes intensity $\lambda(t)$



Temporal partitions



change-point detection

- Bayesian online change-point detection (CPD)**
Estimates the run length variable, the probability of having a change point r days ago

joint distribution

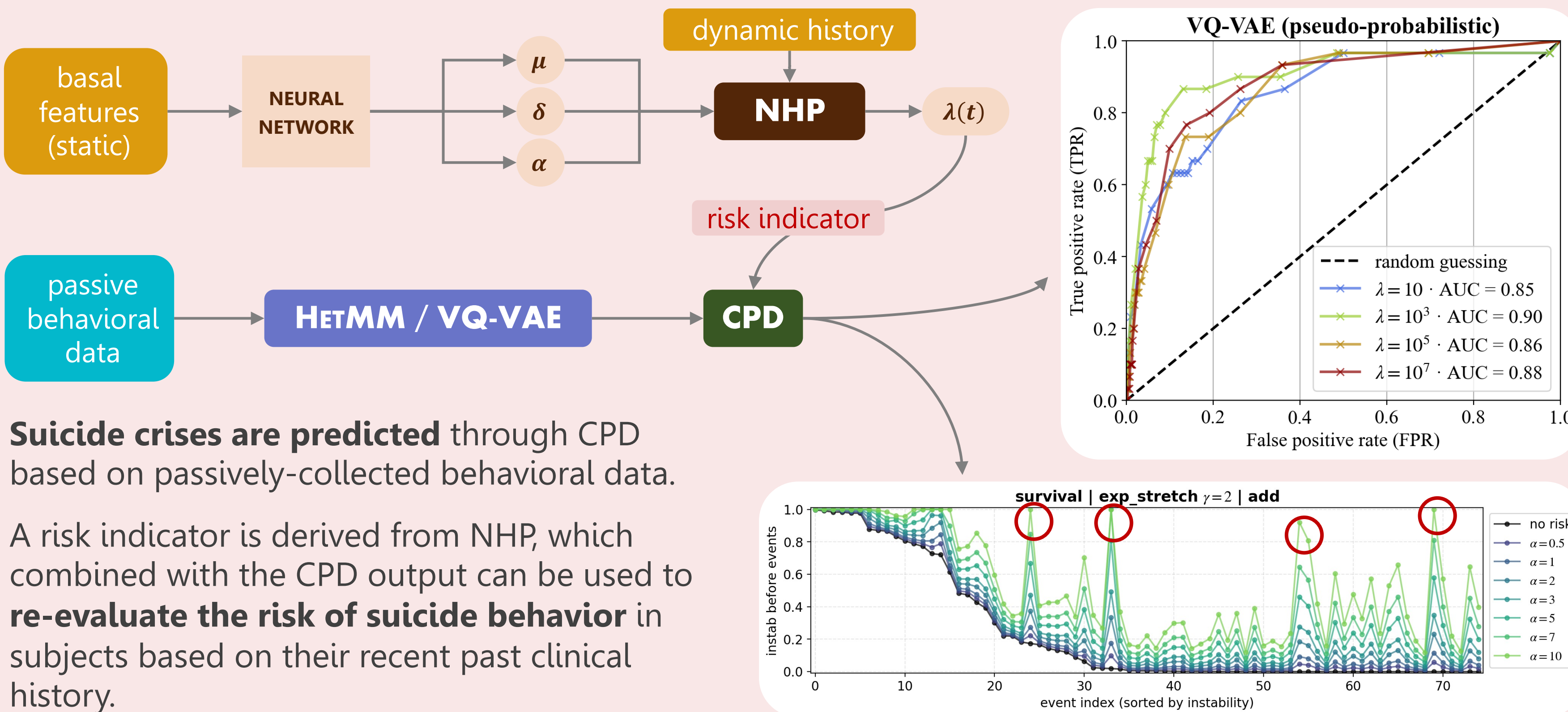
$$p(r_t, \mathbf{z}_{1:t}, \theta_t) = \sum_{r_{t-1}} p(r_t | r_{t-1}) p(\mathbf{z}_t | \theta_t) p(\theta_t | r_{t-1}, \mathbf{z}_{1:t-1}^{(r)}) p(r_{t-1}, \mathbf{z}_{1:t-1})$$

change point prior

predictive posterior

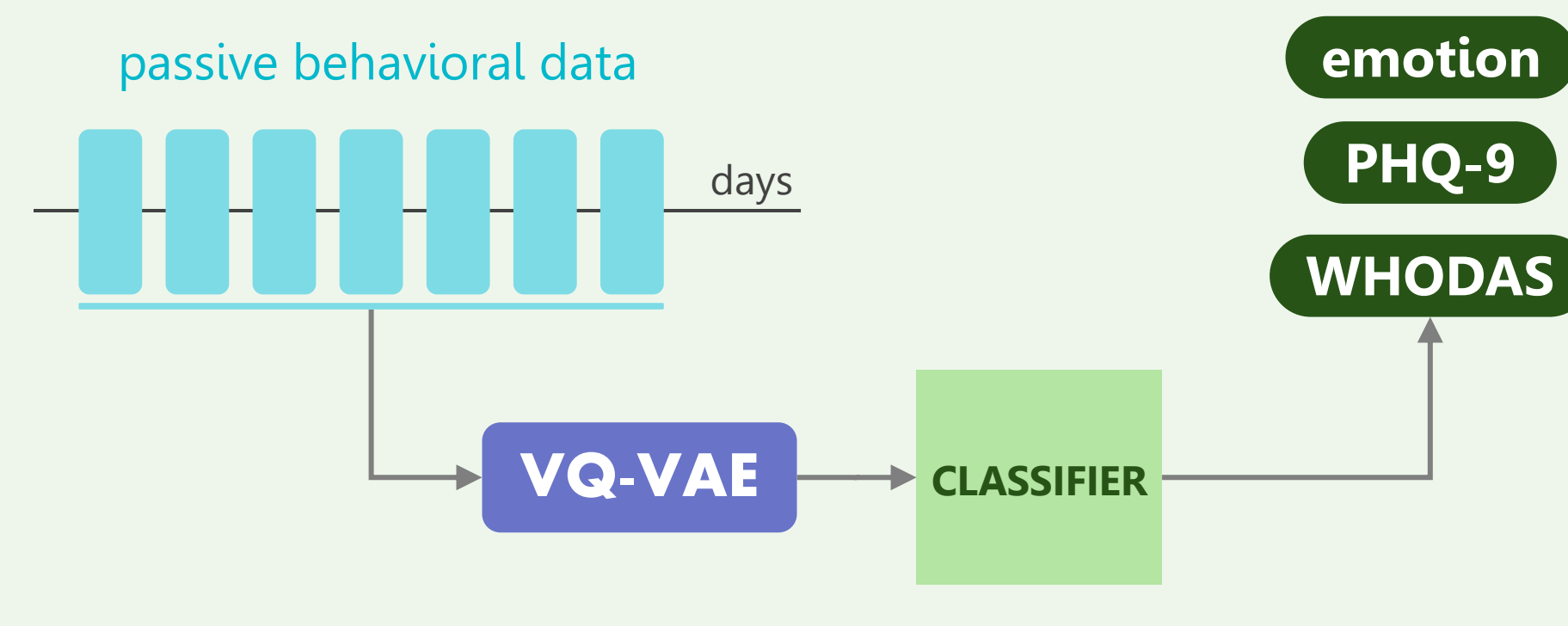
recursive term

Suicide risk assessment



Tasks in progress...

- We characterized the **spontaneity of self-reports**, a first step to understand and model active contributions from patients
- Prediction of clinical scales** as a proxy for clinical states (e.g.: depression, anxiety)



IN REVIEW

- A Vector-Quantized Foundation Model for Patient Behavior Monitoring
- Passive Monitoring for Suicide Risk Prediction in U.S. Military Personnel: Detecting Behavioral Changes with Wearable Data
- Characterizing Spontaneous Emotion Reports on a Smartphone App: A Multimodal Perspective on User Engagement

REFERENCES

- Oliver, Rodrigo, Josué Pérez-Sabater, Leire Paz-Arbaizar, et al. "A Vector-Quantized Foundation Model for Patient Behavior Monitoring." arXiv:2503.15221. Preprint, arXiv, July 14, 2025.
- Larese, Darío C., Pablo M. Olmos, Antonio Artés-Rodríguez, et al. "Modeling Recurrent Suicide Attempts Using Probabilistic Hawkes Processes." *Spanish Journal of Psychiatry and Mental Health*, Feb. 20, 2026.

