Modeling Emotion in Team Coordination

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Motivation

Introduction

- AI can find optimal solutions to most problems.
- Because the human mind is too complex to model, it is easier to apply Simulation Theory and to pretend that the AI's solutions are human's solutions.
- However, humans are irrational. They do not act optimally.

Goal

- Fit a model that explains how emotions influence people's decisions.
- Make predictions about people's future actions.

Approach

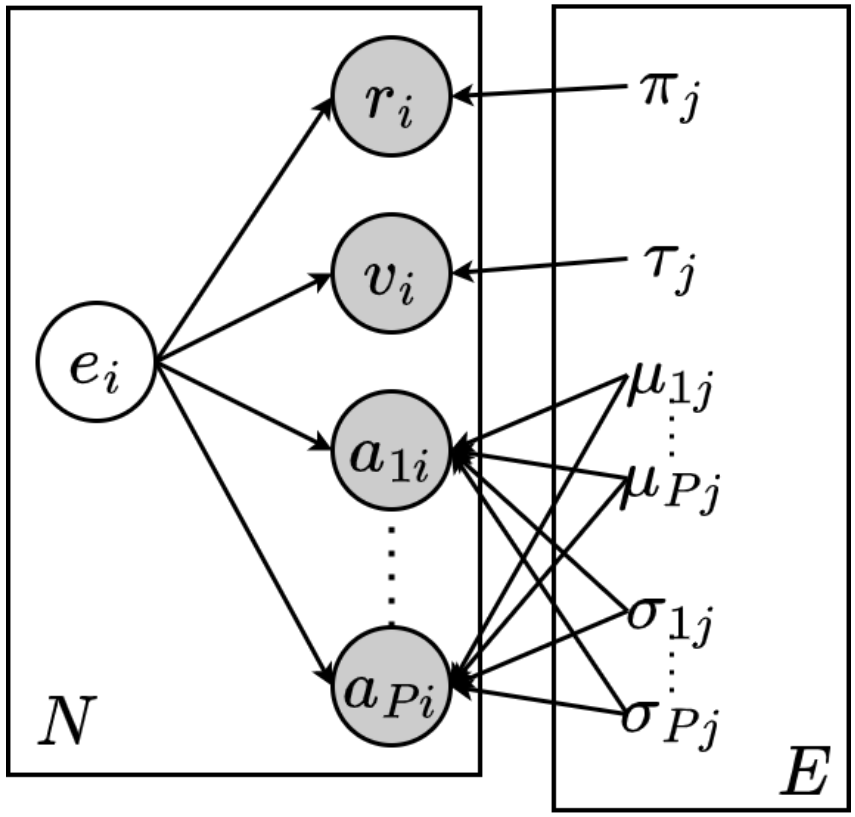
Emotion recognition

- Given observations of facial features a, arousal score r, and valence score v of one person.
- Fit probability distribution parameters μ and σ on facial features a given latent emotion e of one person.

Influence of emotion on team coordination

- Given observations of facial features a, fitted parameters μ and σ, and coordination s.
- Fit probability distribution parameters ϕ on coordination s given latent emotion e of one person.

Emotion Recognition



- a_{pi} is observation i of the summary statistics of action unit p
- v_i is observation i of the valence score of one person
- r_i is observation i of the arousal score of one person
- e_i is i-th latent variable instance of emotion of one person

Emotion Recognition

$$
\begin{aligned}
e_i &\sim \mathrm{Cat}(\frac{1}{E}, \ldots, \frac{1}{E}) \\
r_i &\sim \mathrm{Cat}(\pi_{e_i}) \\
v_i &\sim \mathrm{Cat}(\tau_{e_i}) \\
a_{pi} &\sim \mathrm{TN}(\mu_{e_i}, \sigma_{e_i})
\end{aligned}
$$

$$
\begin{aligned}
& p(e, r, v, a \mid \pi, \tau, \mu, \sigma) \\
&= \prod_k^E \prod_i^N p(e_{ik}) p(v_i \mid e_{ik}) p(r_i \mid e_{ik}) \prod_p^P p(a_{pi} | e_{ik}) \\
&= \prod_k^E \prod_i^N \frac{1}{E} \pi_{kv_i} \tau_{kr_i} \prod_p^P \mathrm{TN}(a_{pi} \mid \mu_{pk}, \sigma_{pk})
\end{aligned}
$$

Emotion Recognition

Because e is a latent variable, use expectation maximization.

$$\arg\max_{\pi,\tau,\mu,\sigma} \mathbb{E}_q[\log p(e, r, v, a \mid \pi, \tau, \mu, \sigma)]$$

$$= \arg\max_{\pi,\tau,\mu,\sigma} \sum_{k}^{E} \sum_{i}^{N} q(e_{ik}) \ \log p(e_{ik}, r_i, v_i, a_i \mid \pi_{kv_i}, \tau_{kr_i}, \mu_k, \sigma_k)$$

E step

$$q(e_{ik}) = p(e_{ik} \mid r_i, v_i, a_{1i\ldots Pi}, \pi^{\text{old}}_{kv_i}, \tau^{\text{old}}_{kr_i}, \mu^{\text{old}}_{1k\ldots Pi}, \sigma^{\text{old}}_{1k\ldots Pk})$$

$$= \frac{\pi^{\text{old}}_{kv_i} \tau^{\text{old}}_{kr_i} \prod_p^P \text{TN}(a_{pi} \mid \mu^{\text{old}}_{pk}, \sigma^{\text{old}}_{pk})}{E^2 \sum_j^E \pi^{\text{old}}_{jv_i} \tau^{\text{old}}_{jr_i} \prod_p^P \text{TN}(a_{pi} \mid \mu^{\text{old}}_{pj}, \sigma^{\text{old}}_{pj})}$$

Emotion Recognition

M step

$$0 = \frac{\partial}{\partial \pi_{\ell m}} \left(\mathbb{E}_q[\log p(e, r, v, a \mid \pi, \tau, \mu, \sigma)] + \sum_k^E \lambda_{k\pi} \left(1 - \sum_j^D \pi_{kj} \right) \right)$$

$$\pi_{\ell m} \propto \sum_i^N \mathbb{I}(v_i = m) q(e_{i\ell})$$

$$\tau_{\ell m} \propto \sum_i^N \mathbb{I}(r_i = m) q(e_{i\ell})$$

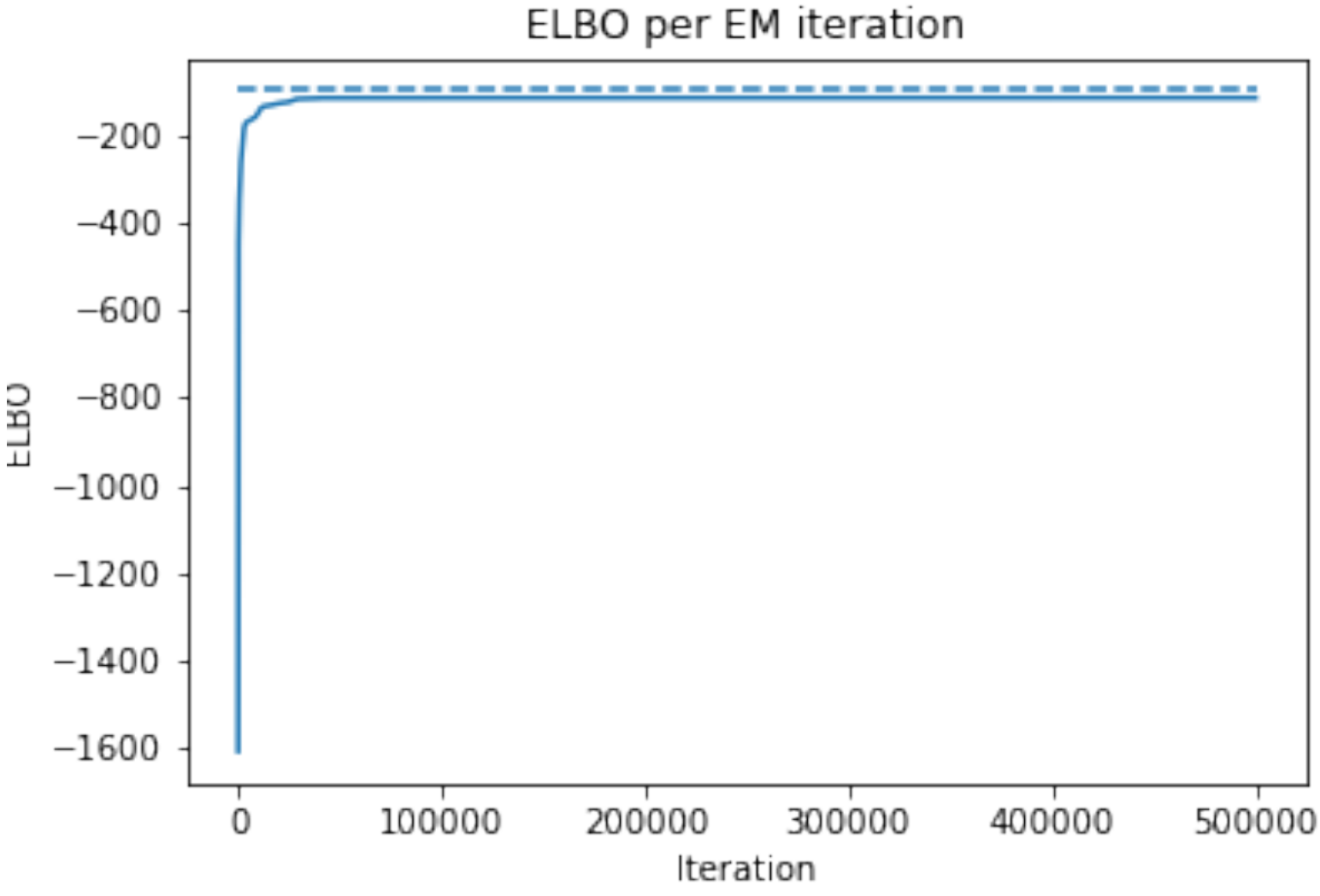
Gradient Ascent (step size α)

$$g_\mu, g_\sigma = \nabla_{\mu,\sigma} \mathbb{E}_q[\log p(e, r, v, a \mid \pi, \tau, \mu, \sigma)]$$

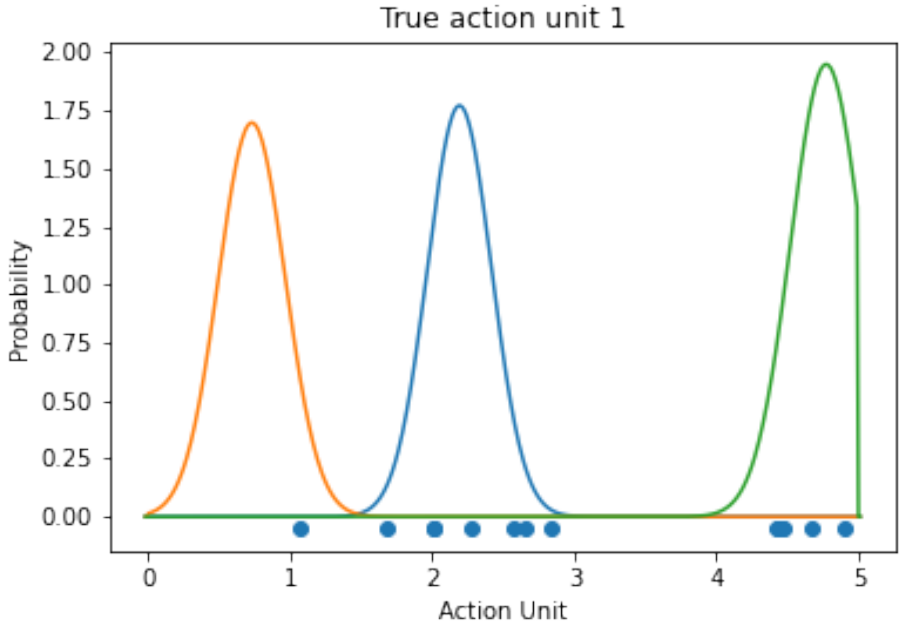
$$\mu_{p\ell} = \mu_{p\ell}^{\text{old}} + \alpha g_{\mu_{p\ell}}$$

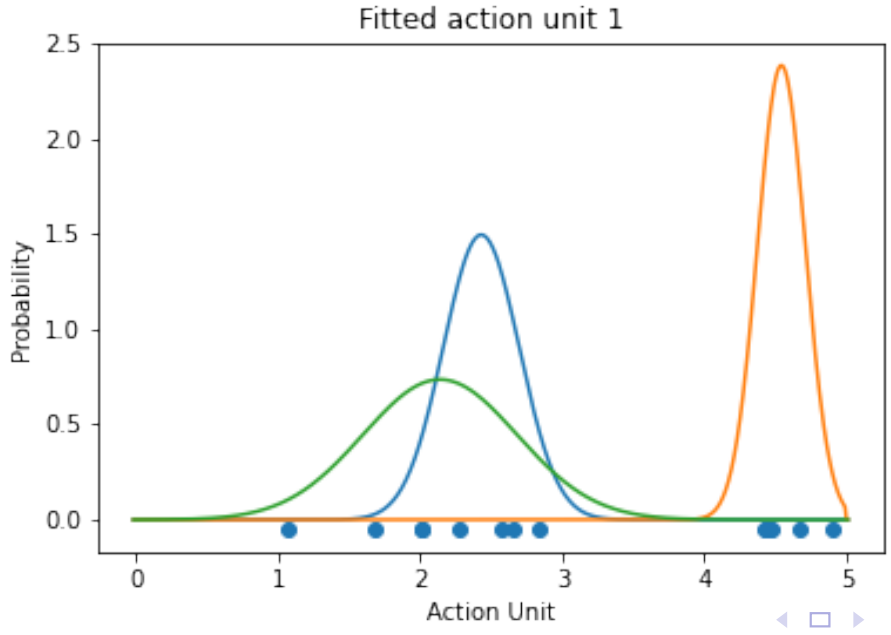
$$\sigma_{p\ell} = \max(\sigma_{p\ell}^{\text{old}} + \alpha g_{\sigma_{p\ell}}, 0)$$

Emotion Recognition (synthetic data)

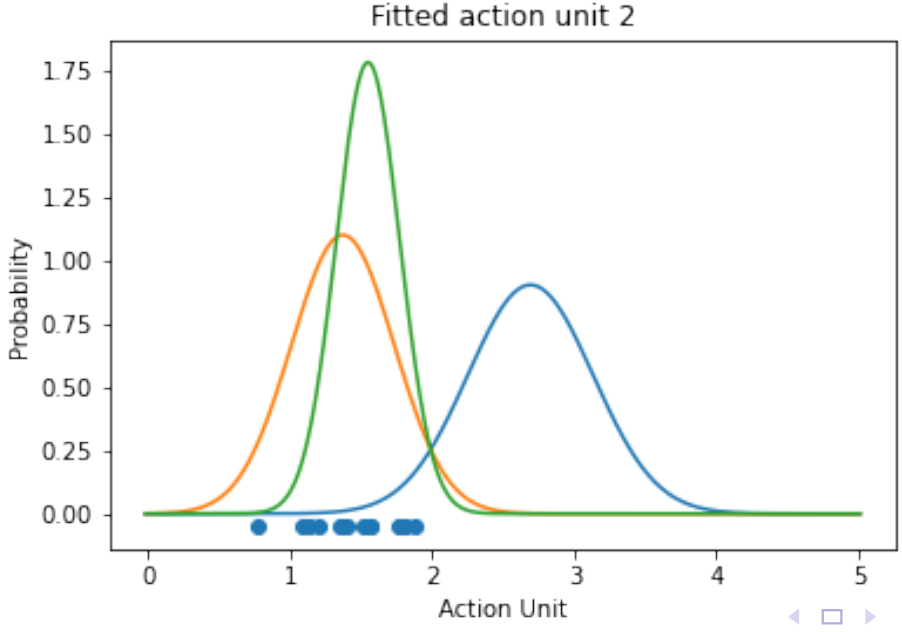


Emotion Recognition (synthetic data)



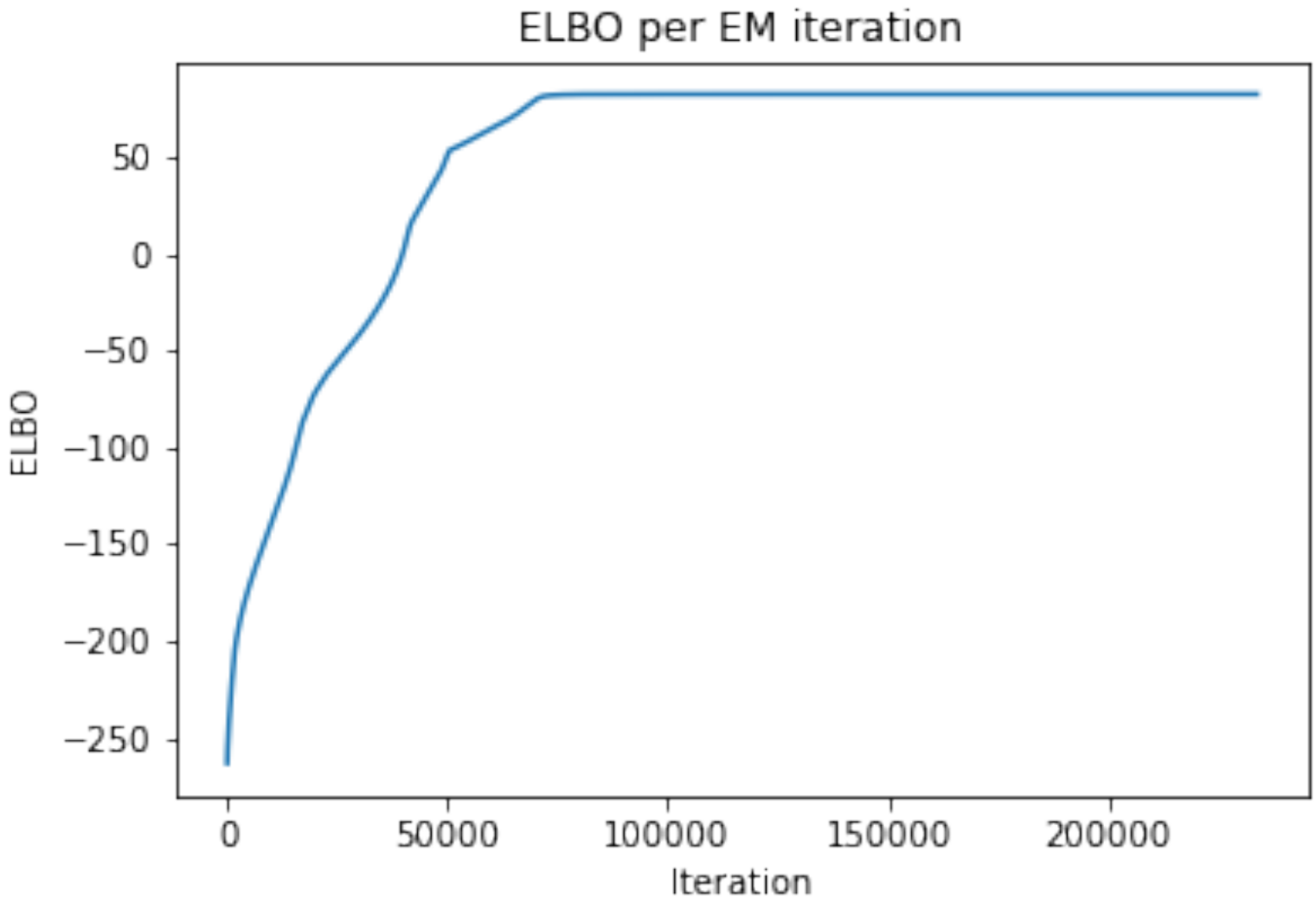


Emotion Recognition (synthetic data)

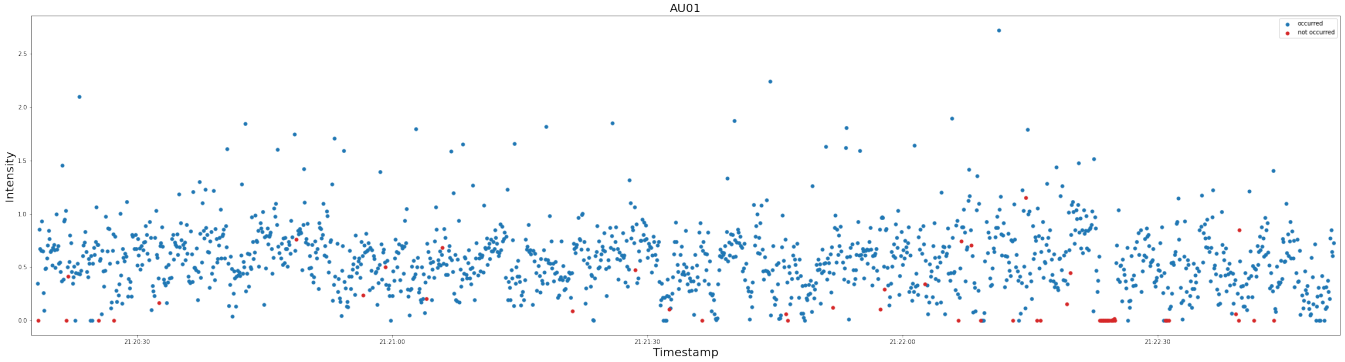


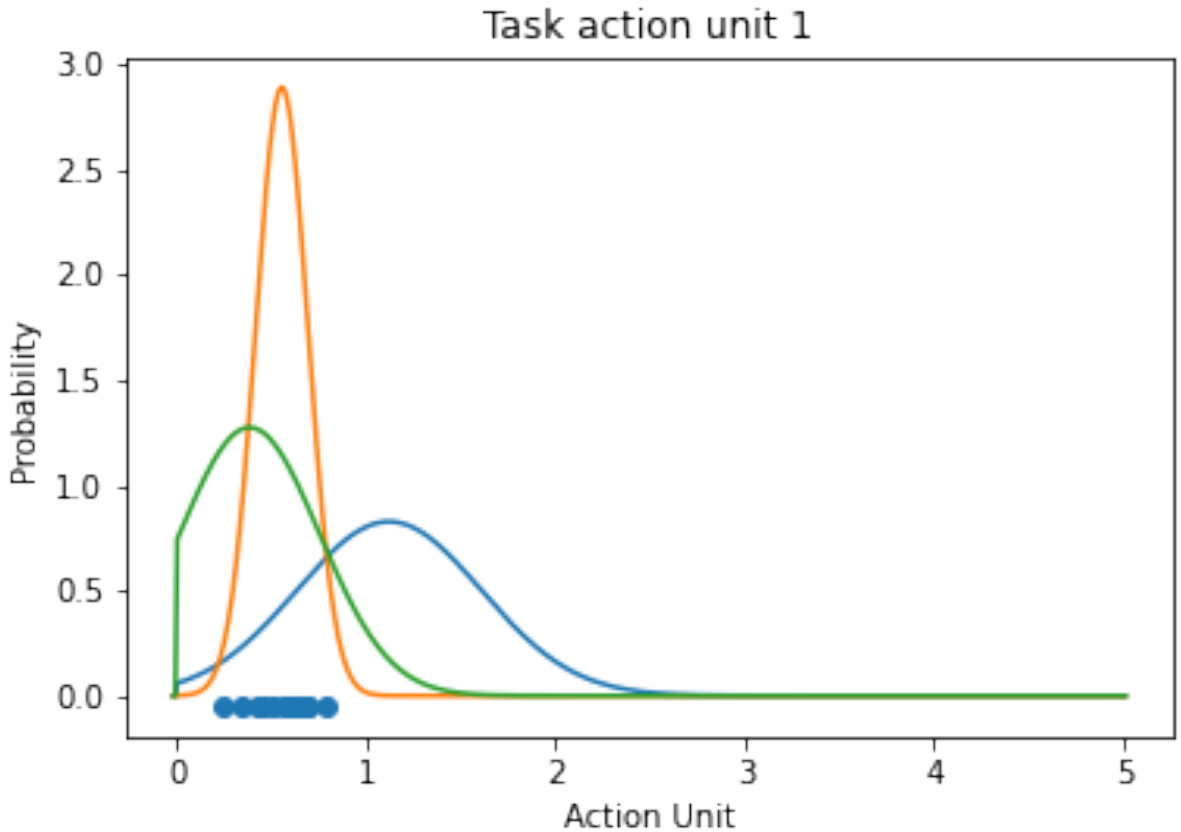
Emotion Recognition (task data)

Fit with 3 categories of emotions

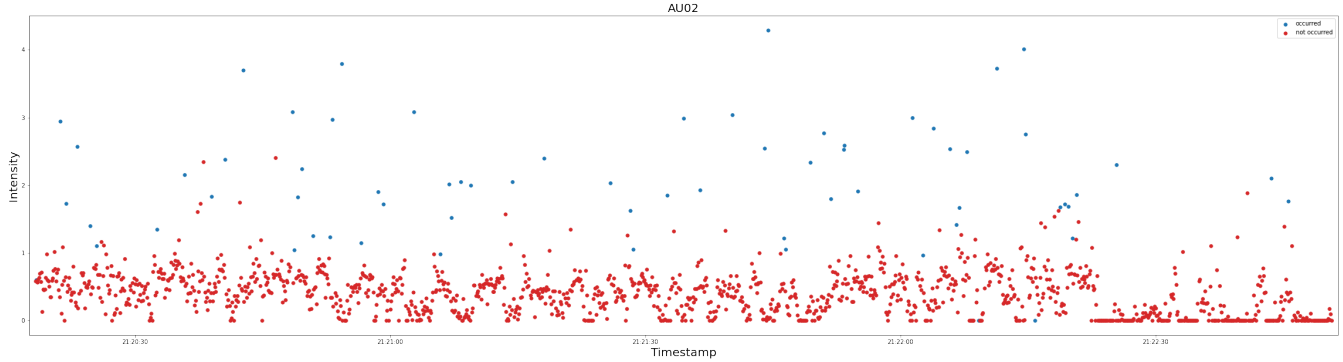


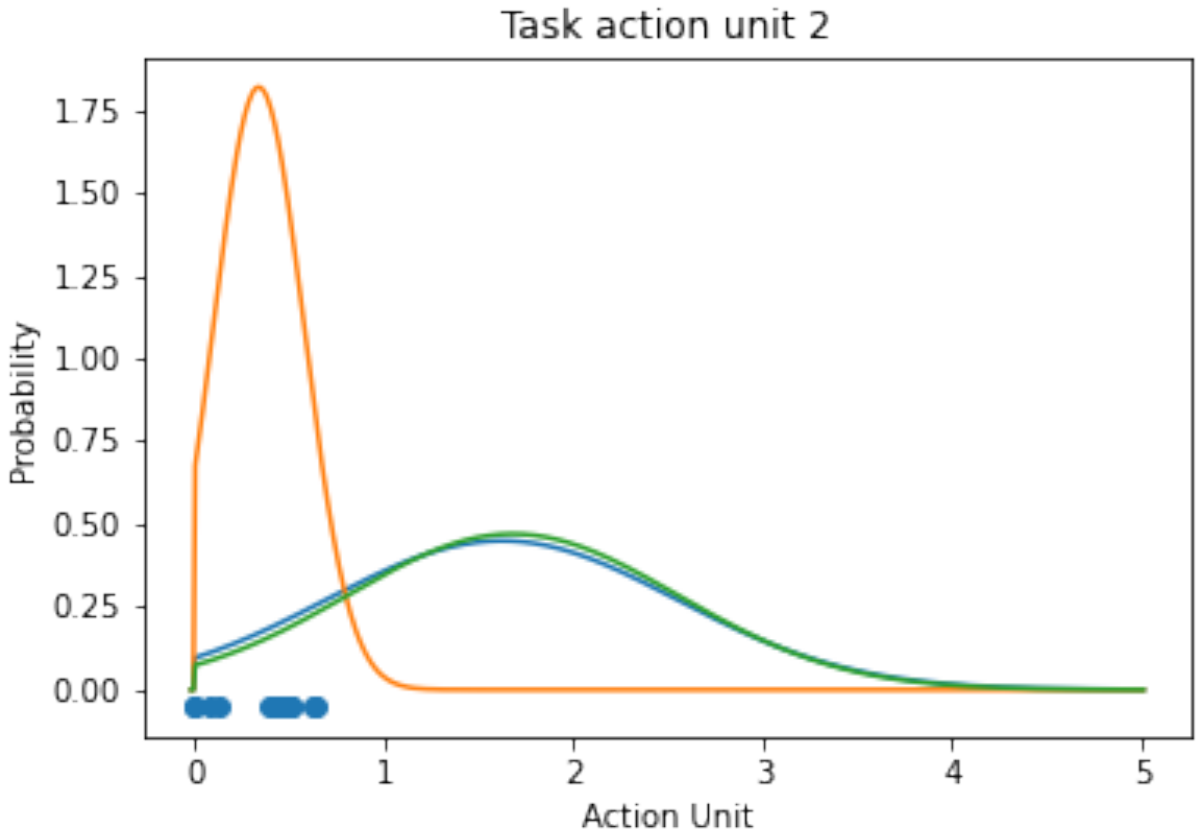
Emotion Recognition (task data)



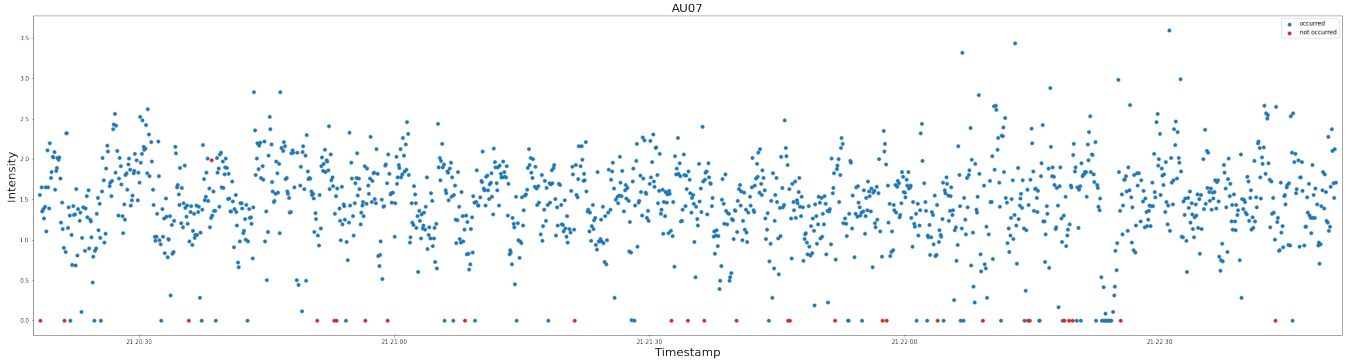


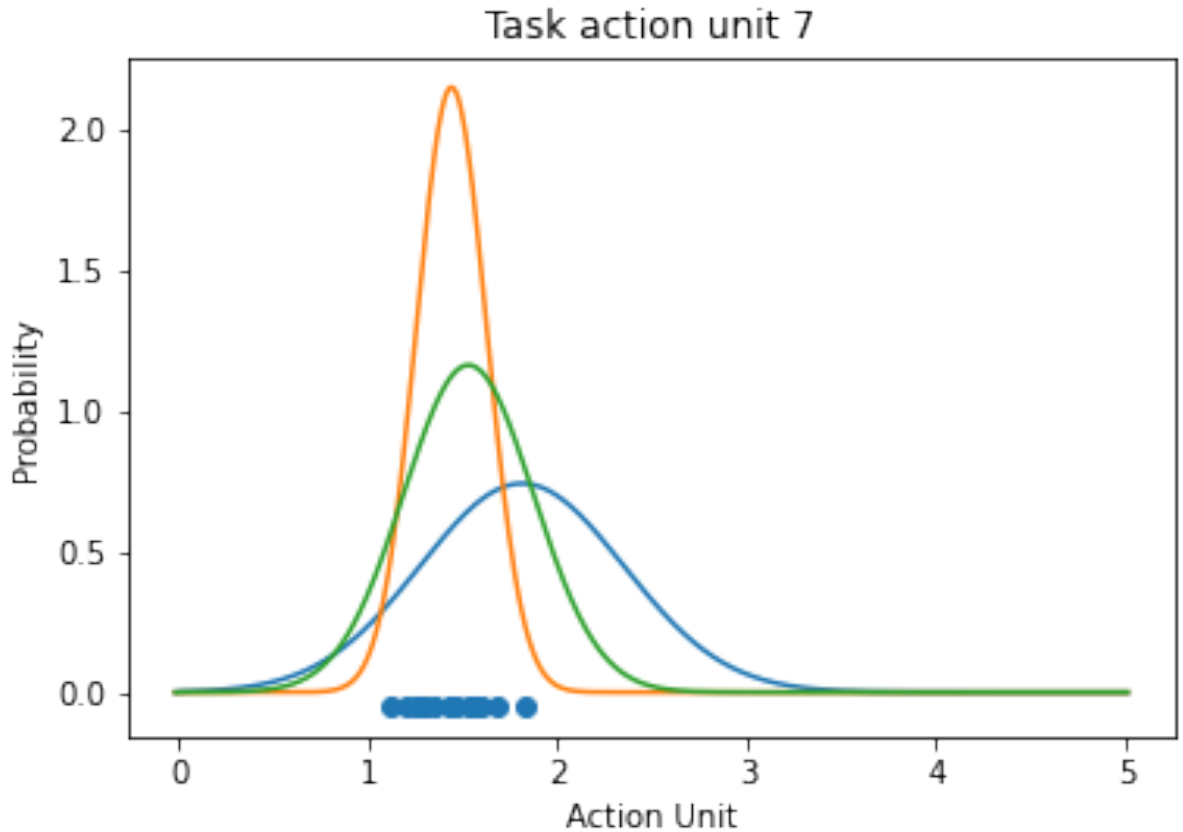
Emotion Recognition (task data)



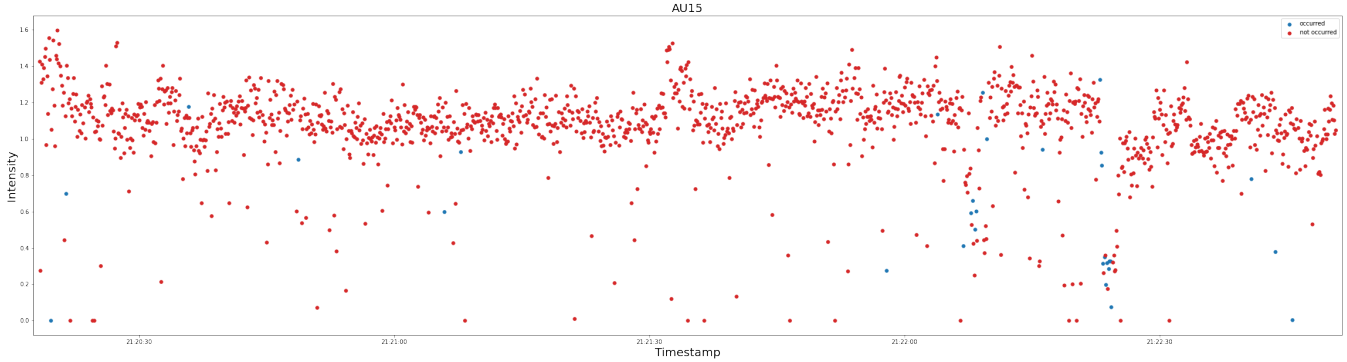


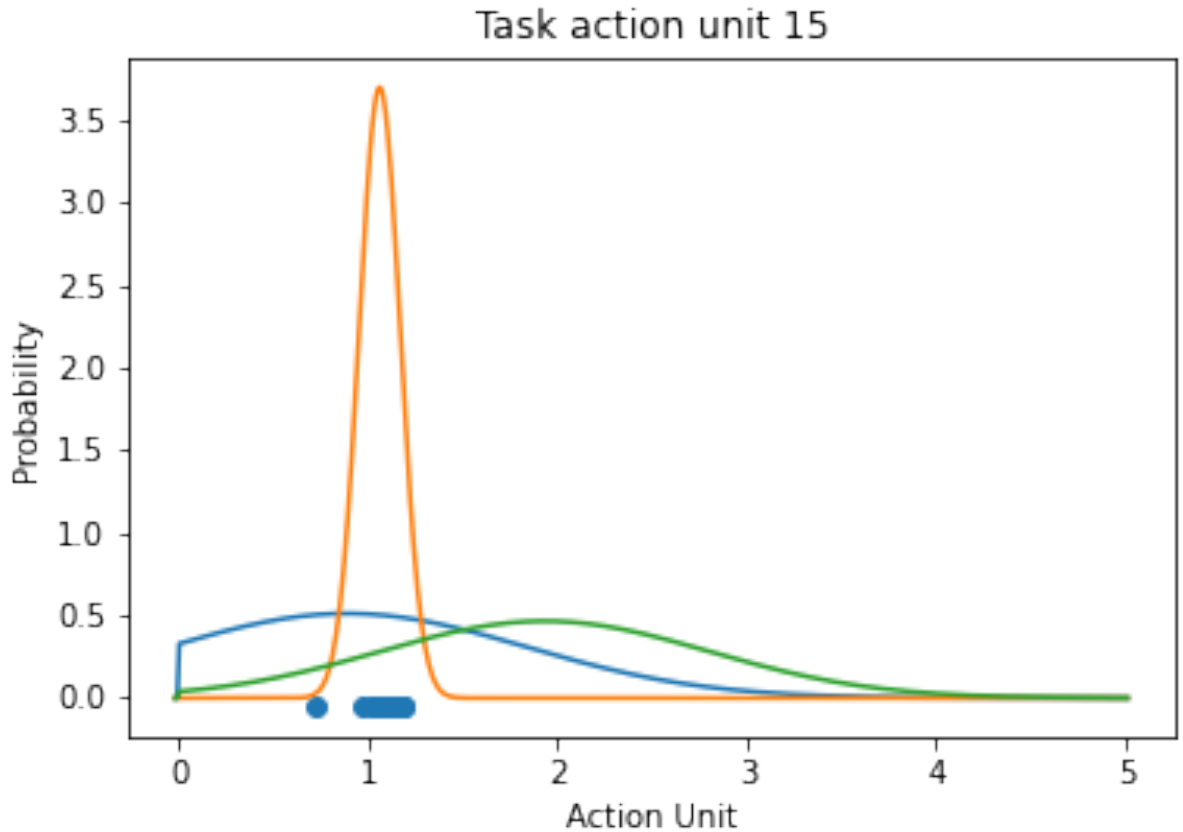
Emotion Recognition (task data)



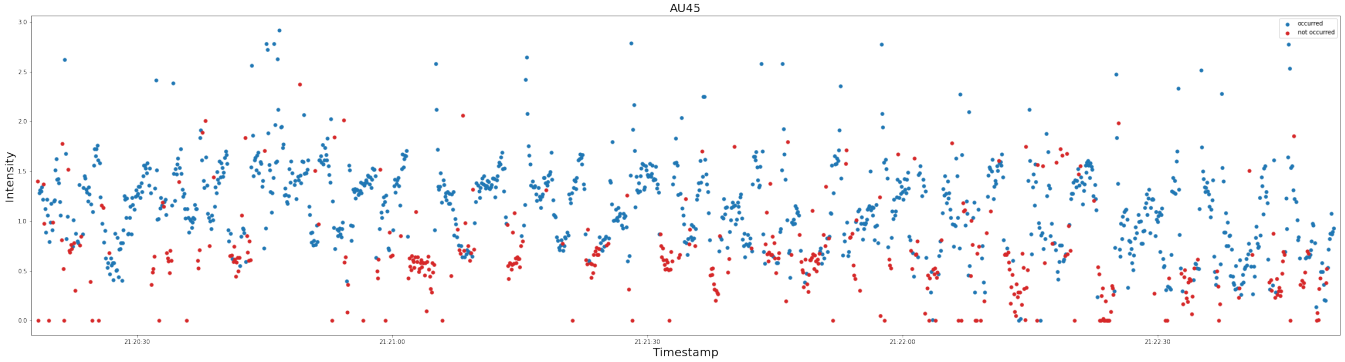


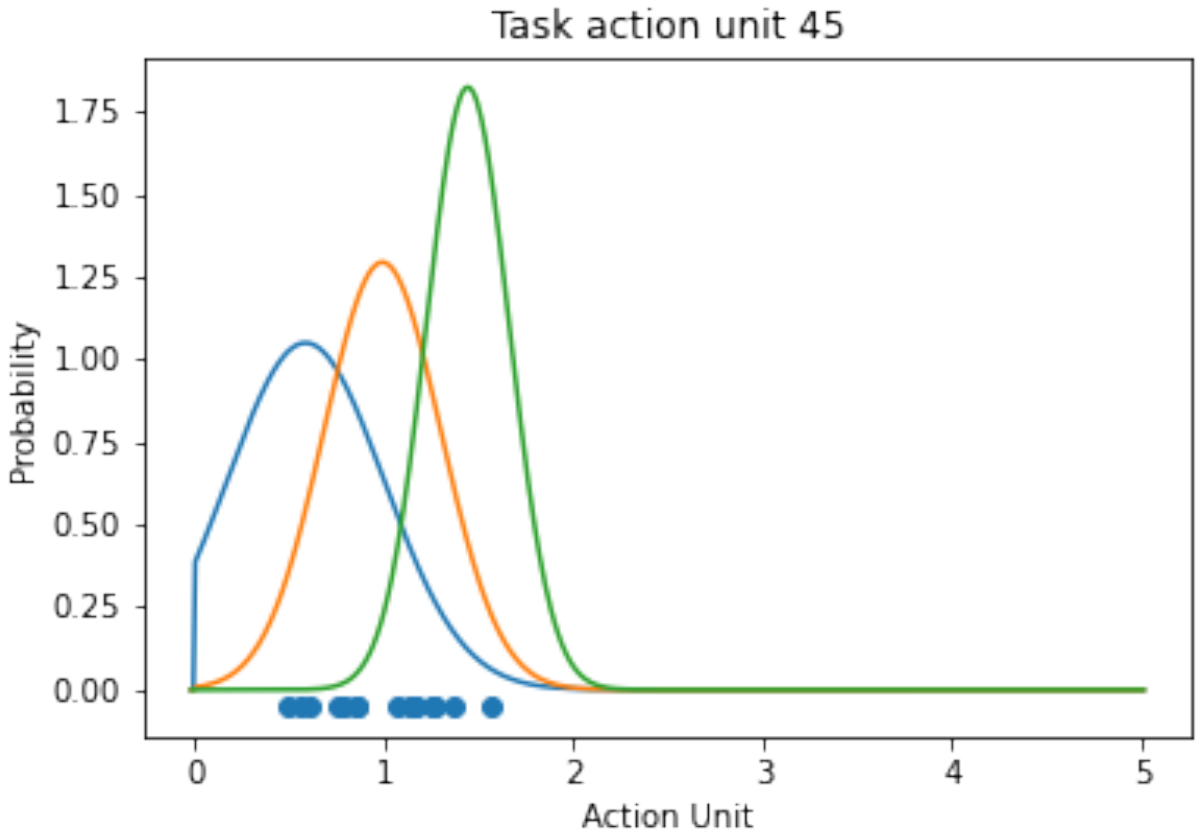
Emotion Recognition (task data)



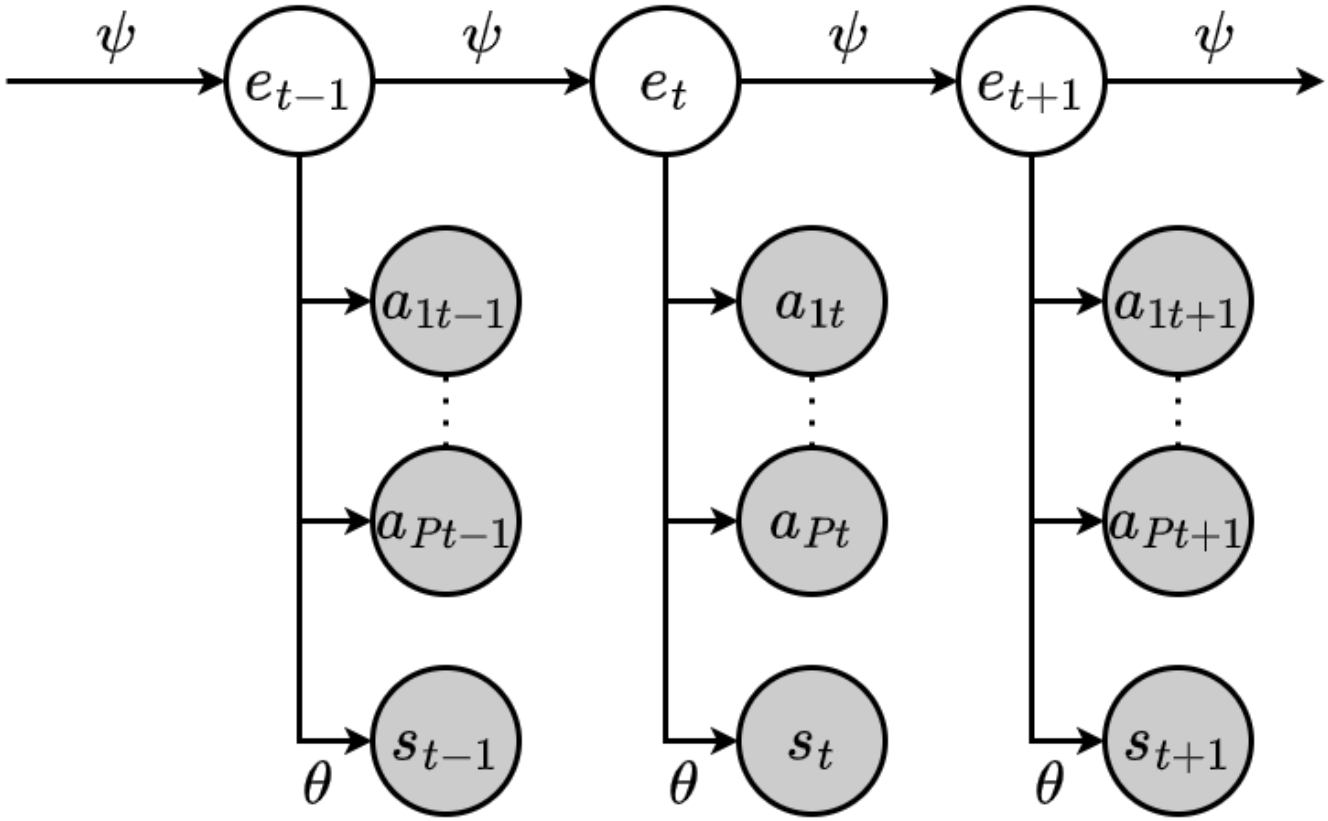


Emotion Recognition (task data)





Influence of Emotion on Team Coordination



- a_{pt} is observation t of the summary statistics of action unit p
- s_t is observation t of coordination of one person
- e_t is t-th latent variable instance of emotion of one person

Influence of Emotion on Team Coordination

$$
\begin{aligned}
e_t &\sim \mathrm{Cat}(\psi_{e_{t-1}}) \\
s_t &\sim \mathrm{Cat}(\theta_{e_t}) \\
a_{pt} &\sim \mathrm{TN}(\mu_{e_t}, \sigma_{e_t})
\end{aligned}
$$

$$
\begin{aligned}
&p(e, s, a \mid \psi, \theta, \mu, \sigma) \\
&= \prod_{k}^{E} \prod_{t}^{T} p(e_{tk} \mid e_{t-1,k}) p(s_t \mid e_{tk}) \prod_{p}^{P} p(a_{pt} | e_{tk}) \\
&= \prod_{k}^{E} \prod_{t}^{T} \psi_{e_{t-1,k}} \theta_{k s_t} \prod_{p}^{P} \mathrm{TN}(a_{pt} \mid \mu_{pk}, \sigma_{pk})
\end{aligned}
$$

Influence of Emotion on Team Coordination

I will use the Baum-Welch algorithm to fit ψ and θ using the fitted μ and σ from the affective task.