

# Should I stay or should I go? Adaption of human observers to the volatility of visual inputs

Laurent Perrinet



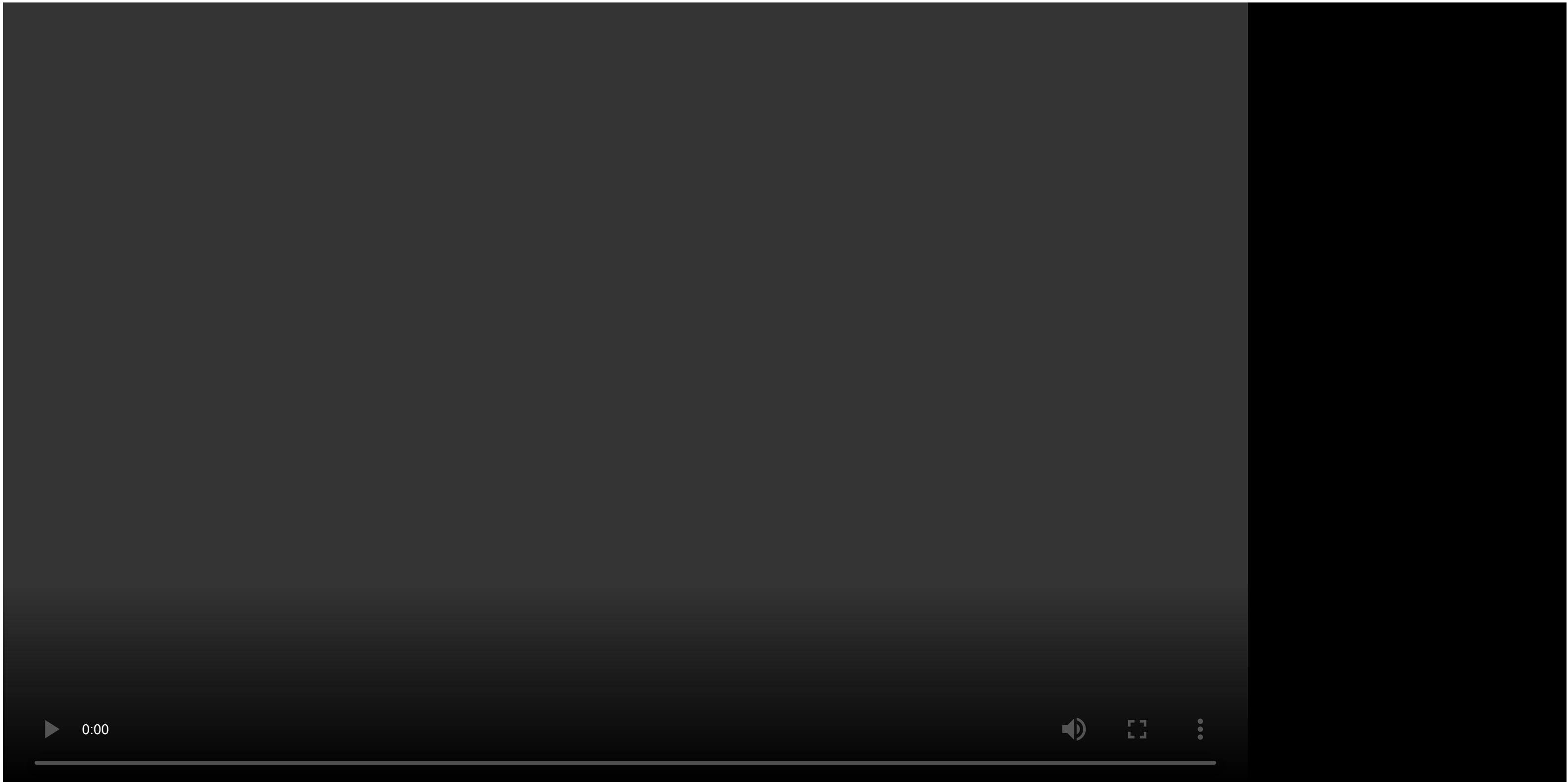
CausaL Kick-off, 5/4/2019

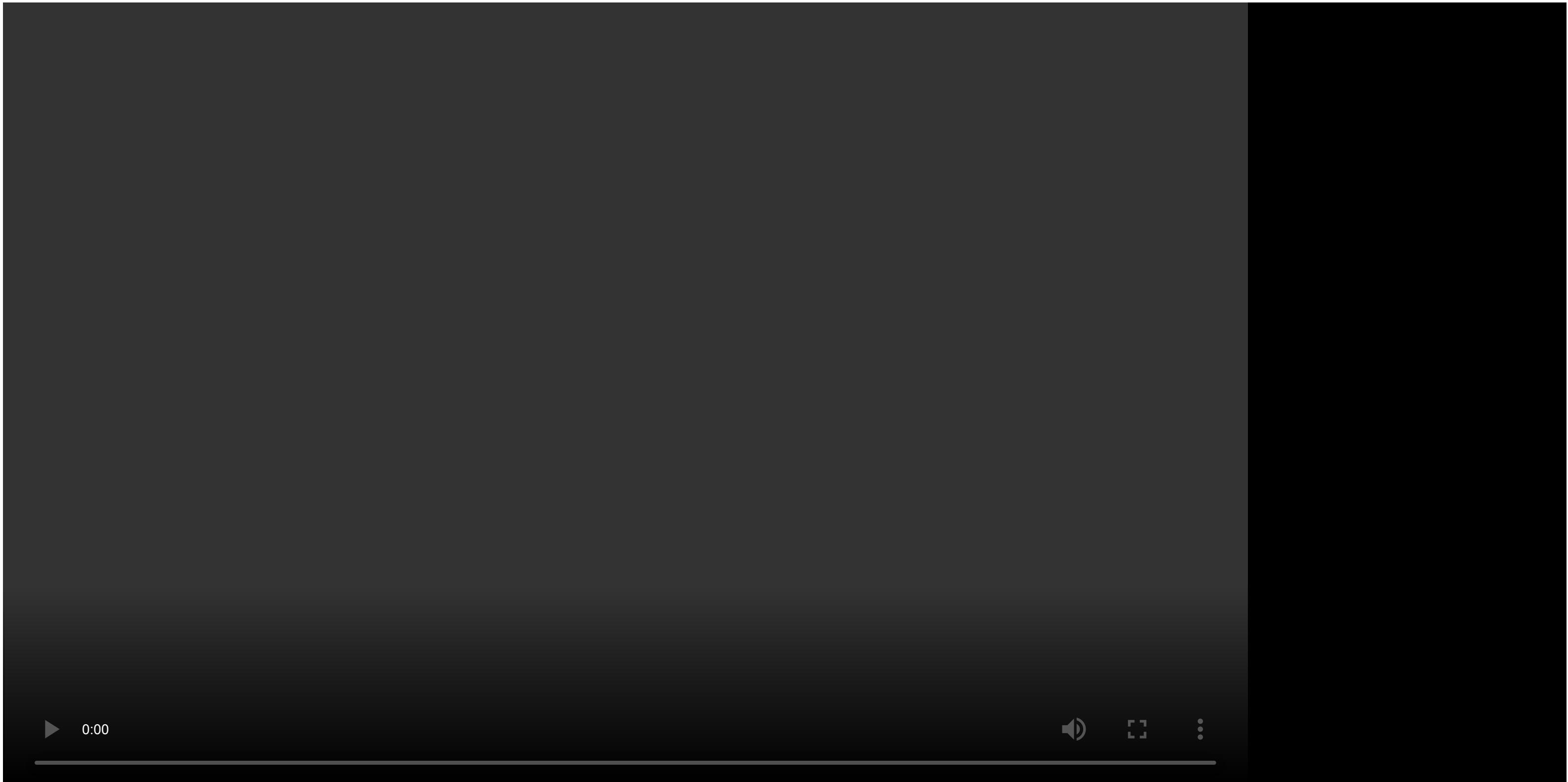
Acknowledgements:

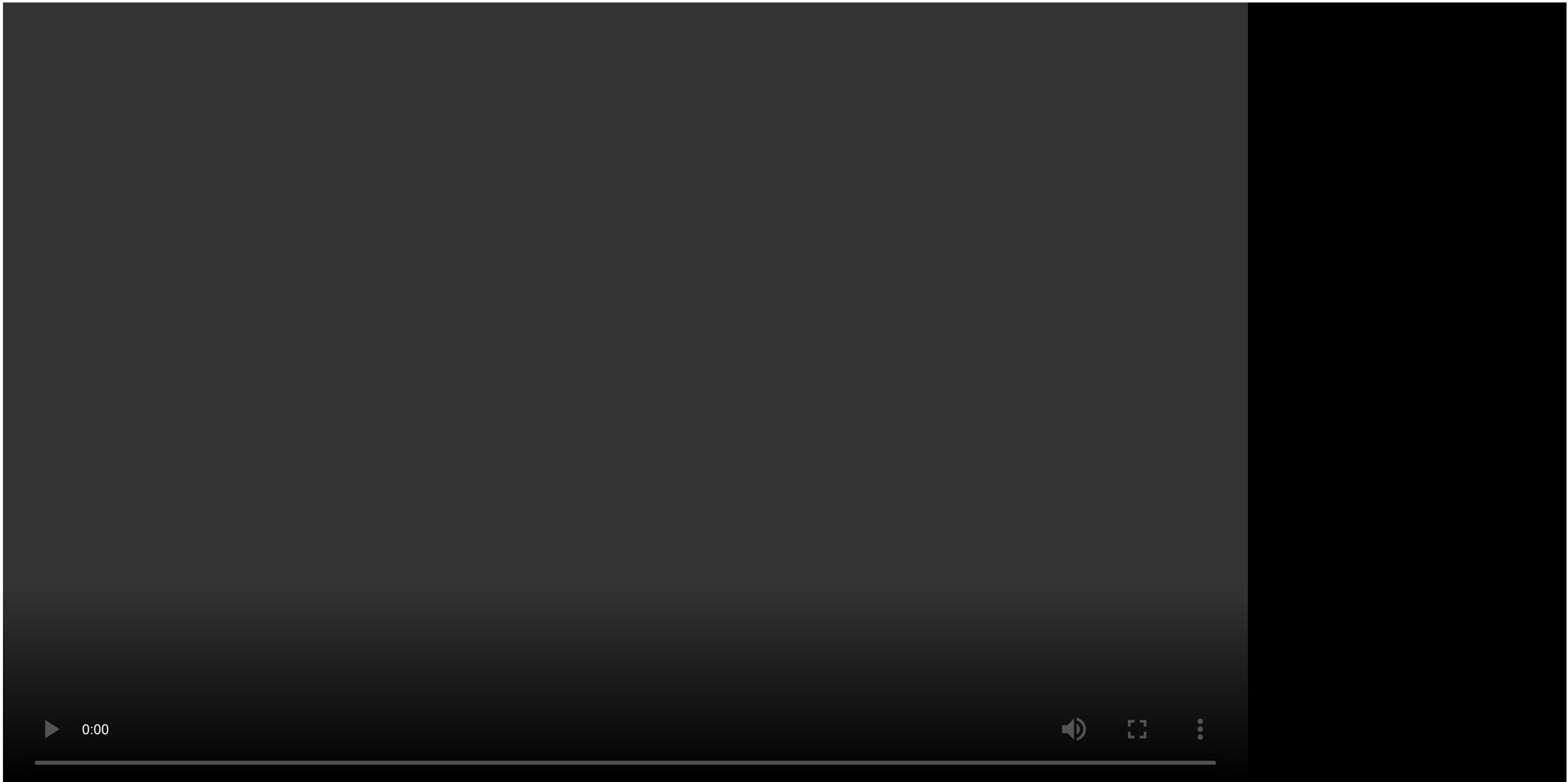
- Rick Adams and Karl Friston @ UCL - Wellcome Trust Centre for Neuroimaging
- Jean-Bernard Damasse, Laurent Madelain and Anna Montagnini - ANR REM
- Frédéric Chavane - INT



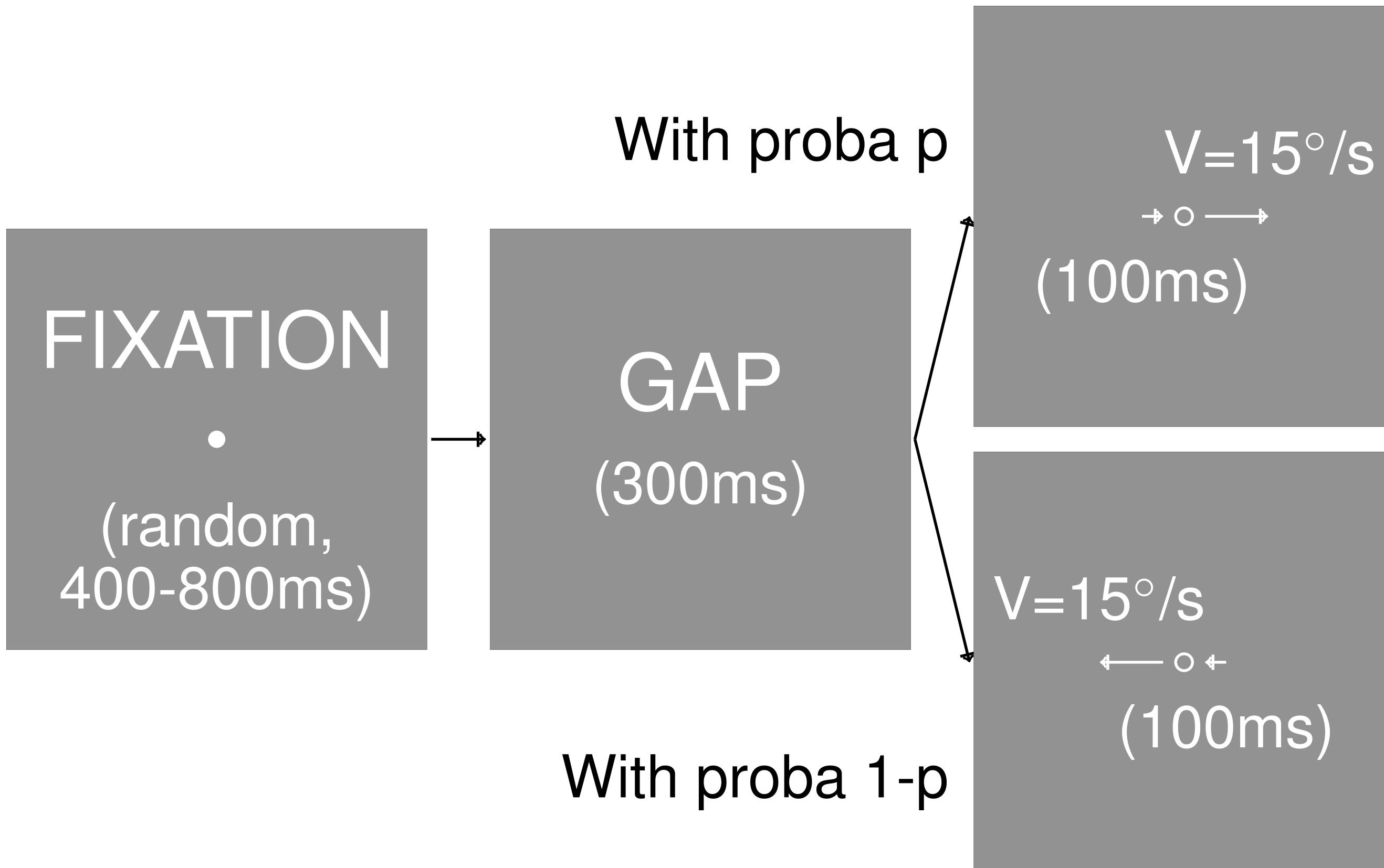
This work was supported by ANR project ANR-18-AAPG-“CAUSAL, Cognitive Architectures of Causal Learning”.



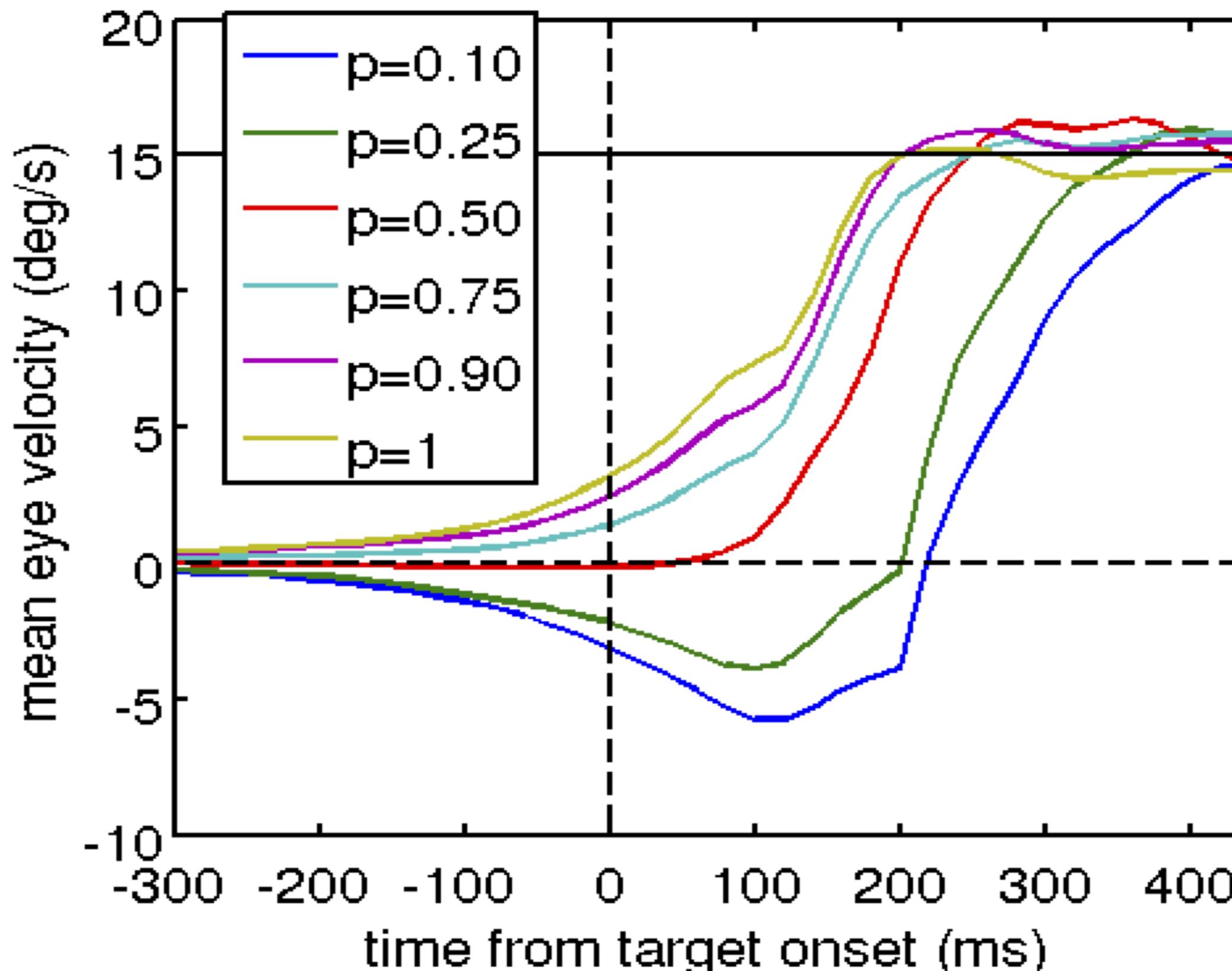




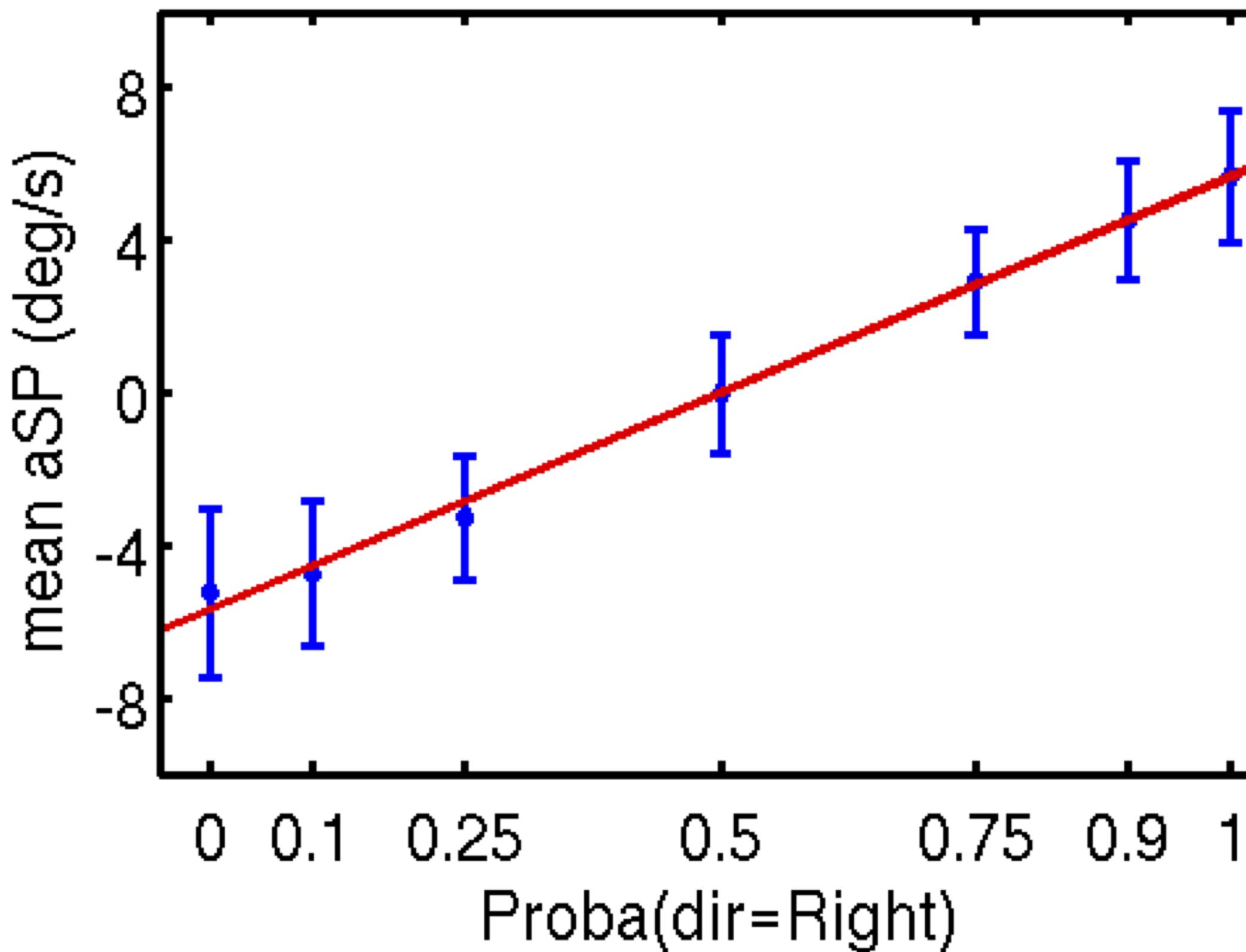
# Should I stay or should I go? - Eye Movements

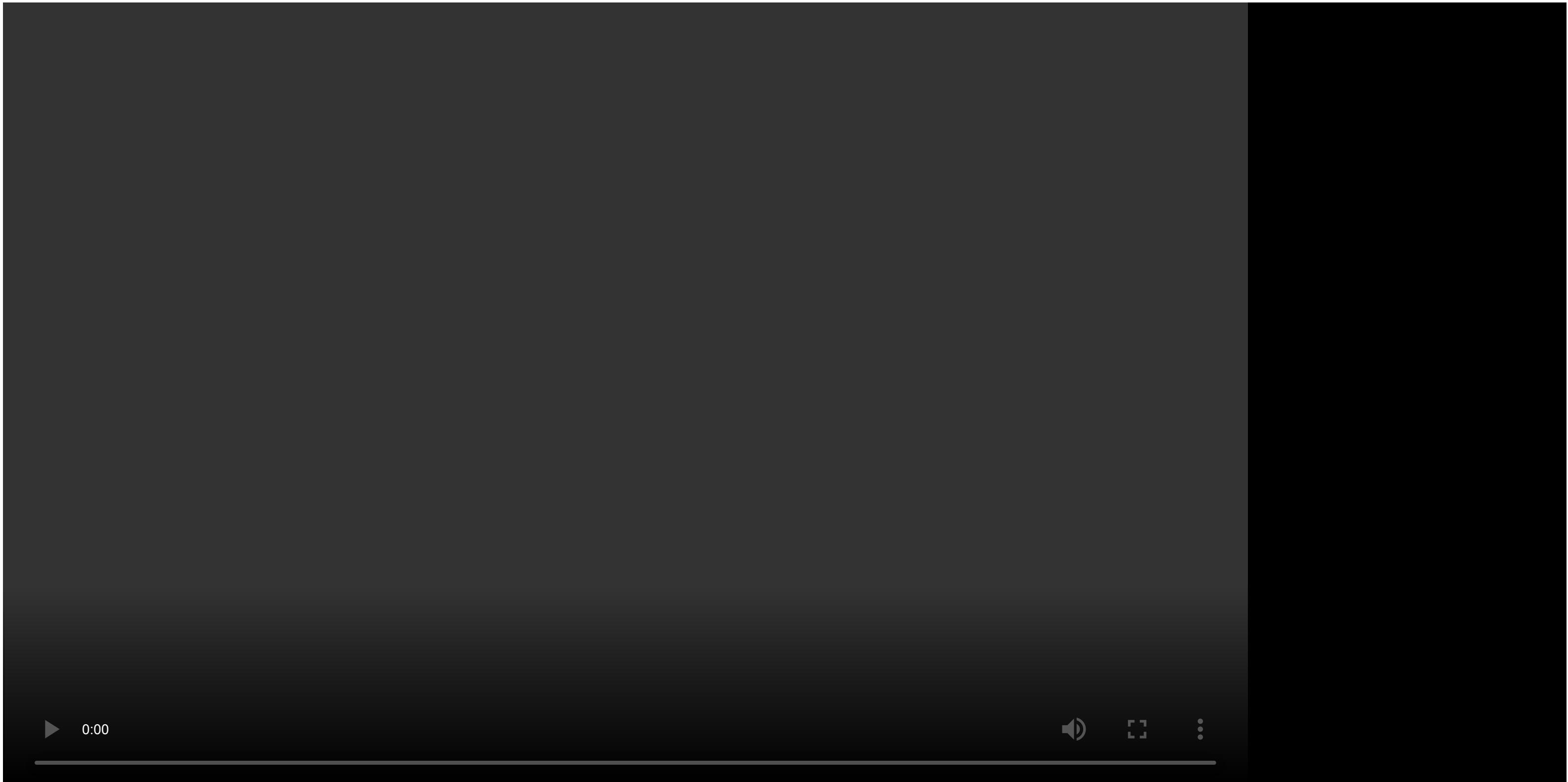


# Should I stay or should I go? - Eye Movements

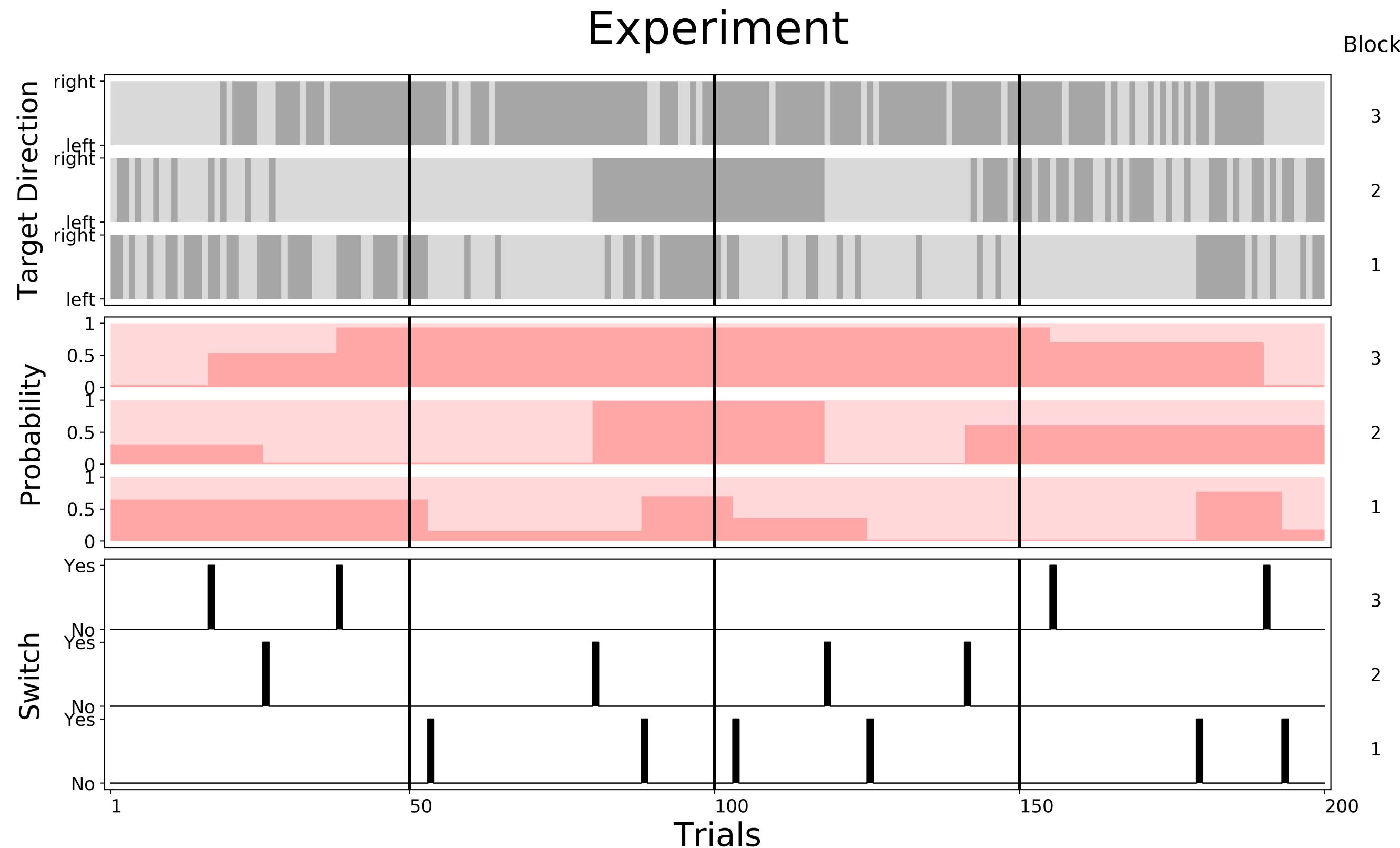


# Should I stay or should I go? - Eye Movements





# Should I stay or should I go? - Random-length block design



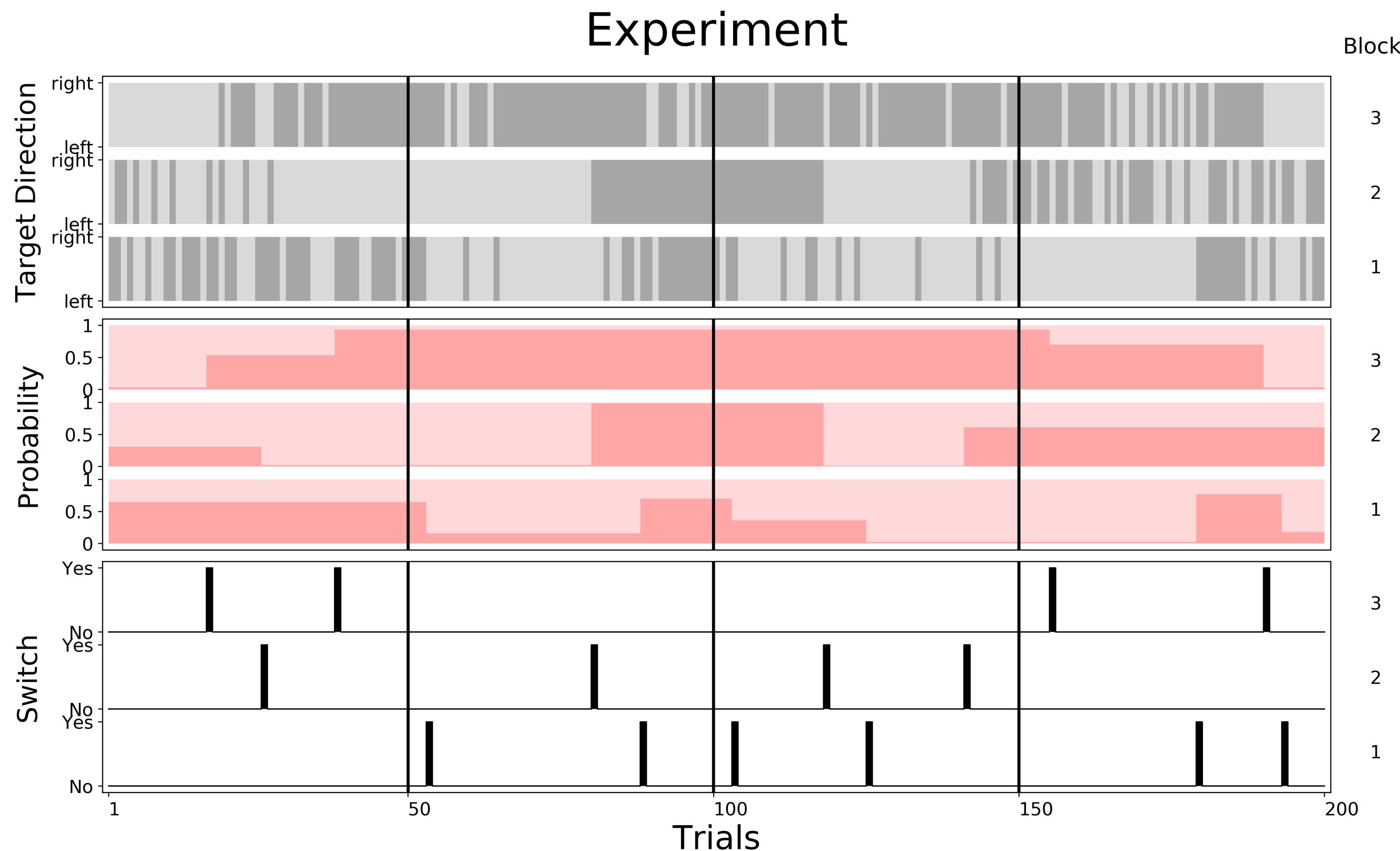
# Outline

1. Should I stay or should I go?
2. Experimental protocol
3. The Bayesian Changepoint Detector
4. Results using the BCP
5. Application to RL?

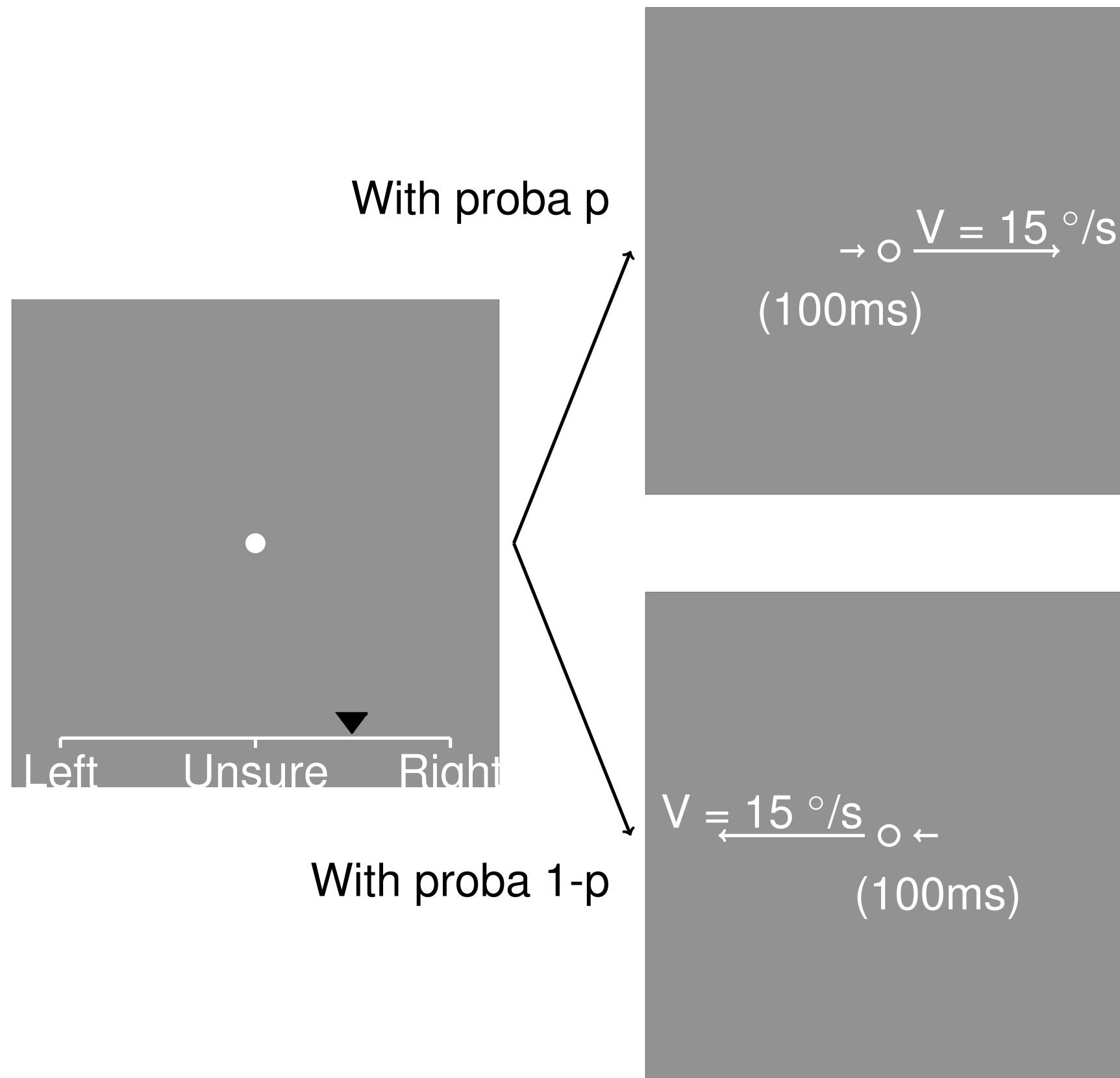
# Outline

1. Should I stay or should I go?
2. Experimental protocol
3. The Bayesian Changepoint Detector
4. Results using the BCP
5. Application to RL?

# Experimental protocol - Random-length block design

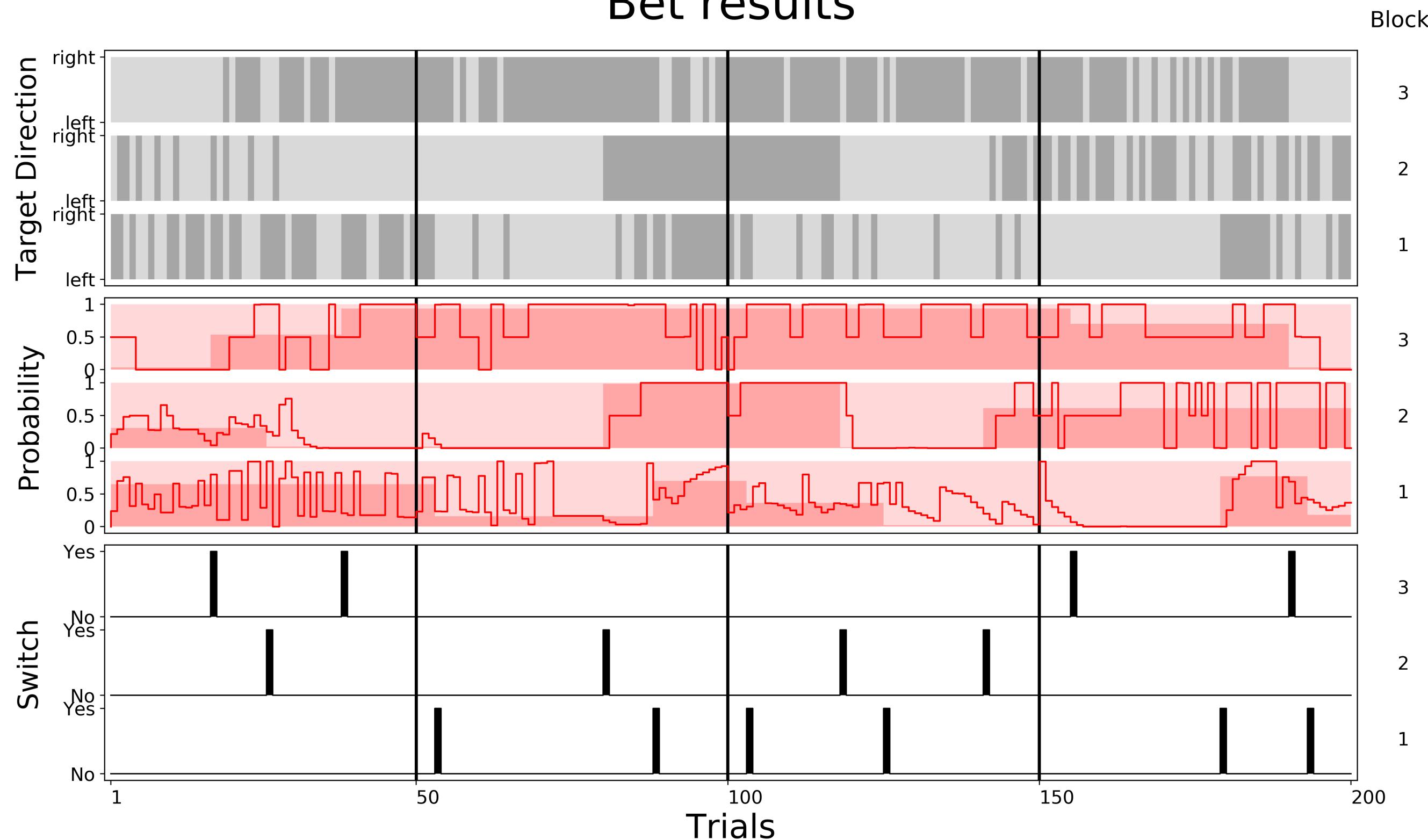


# Experimental protocol - Random-length block design

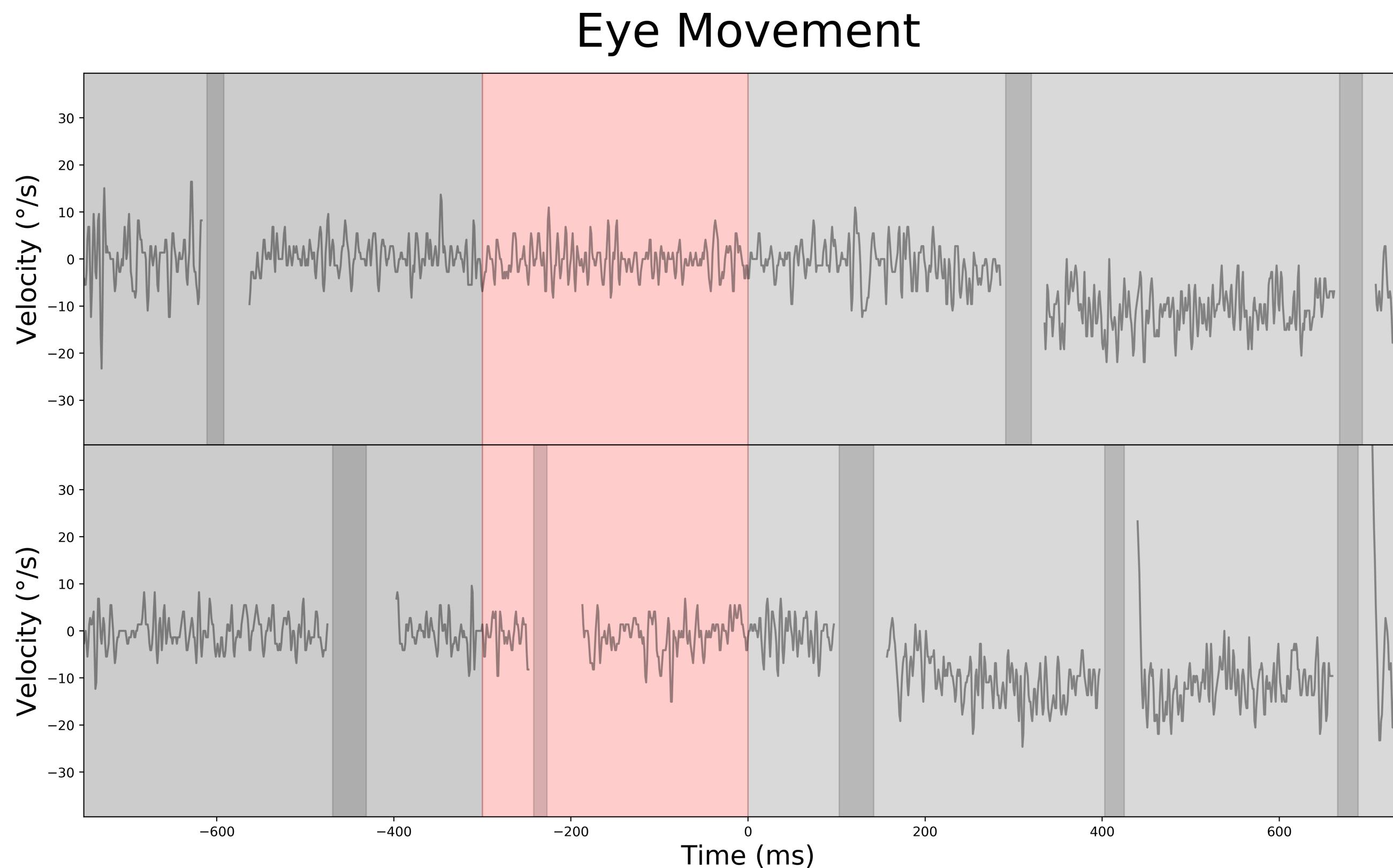


# Experimental protocol

## Bet results

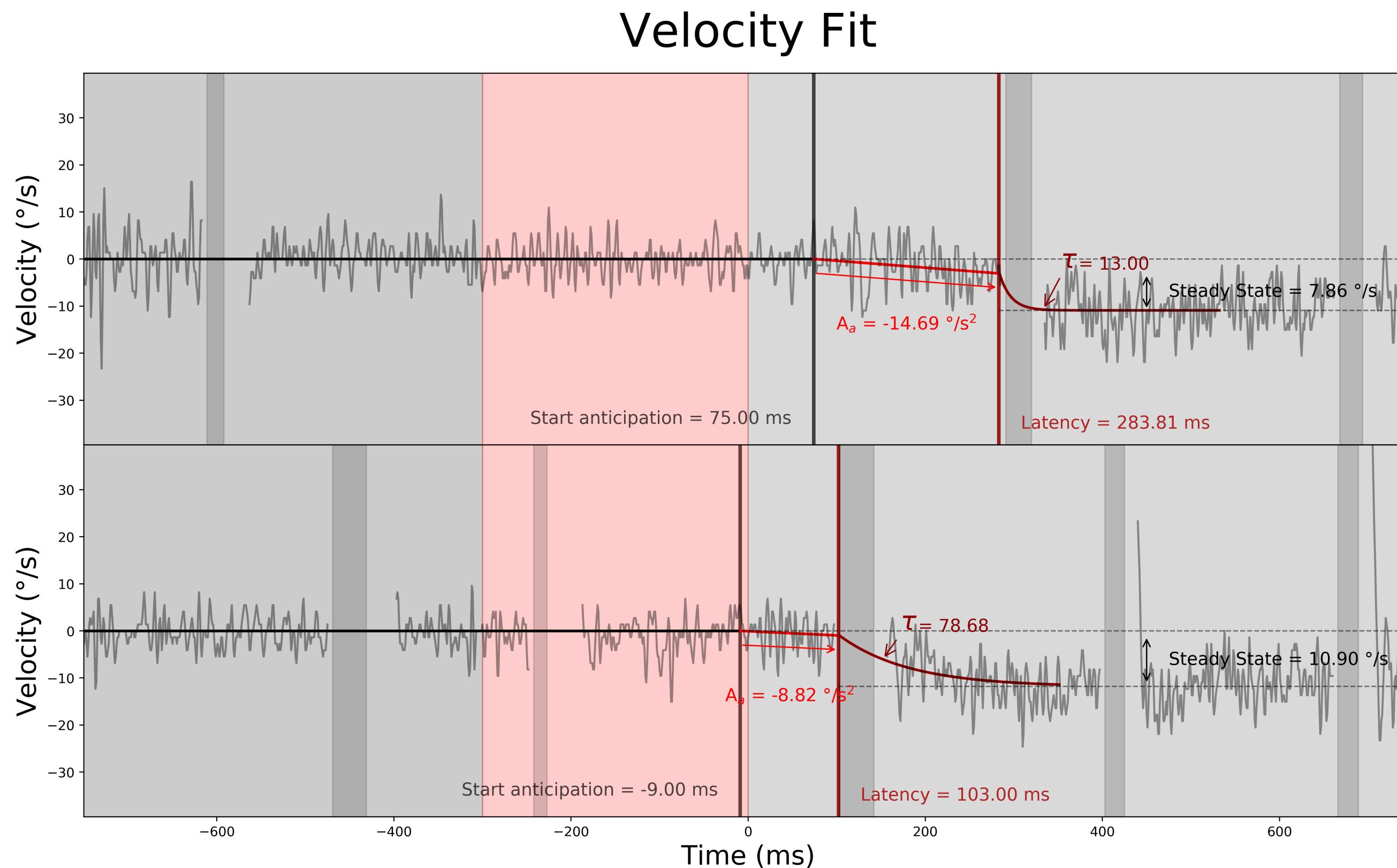


# Experimental protocol - Fitting eye movements



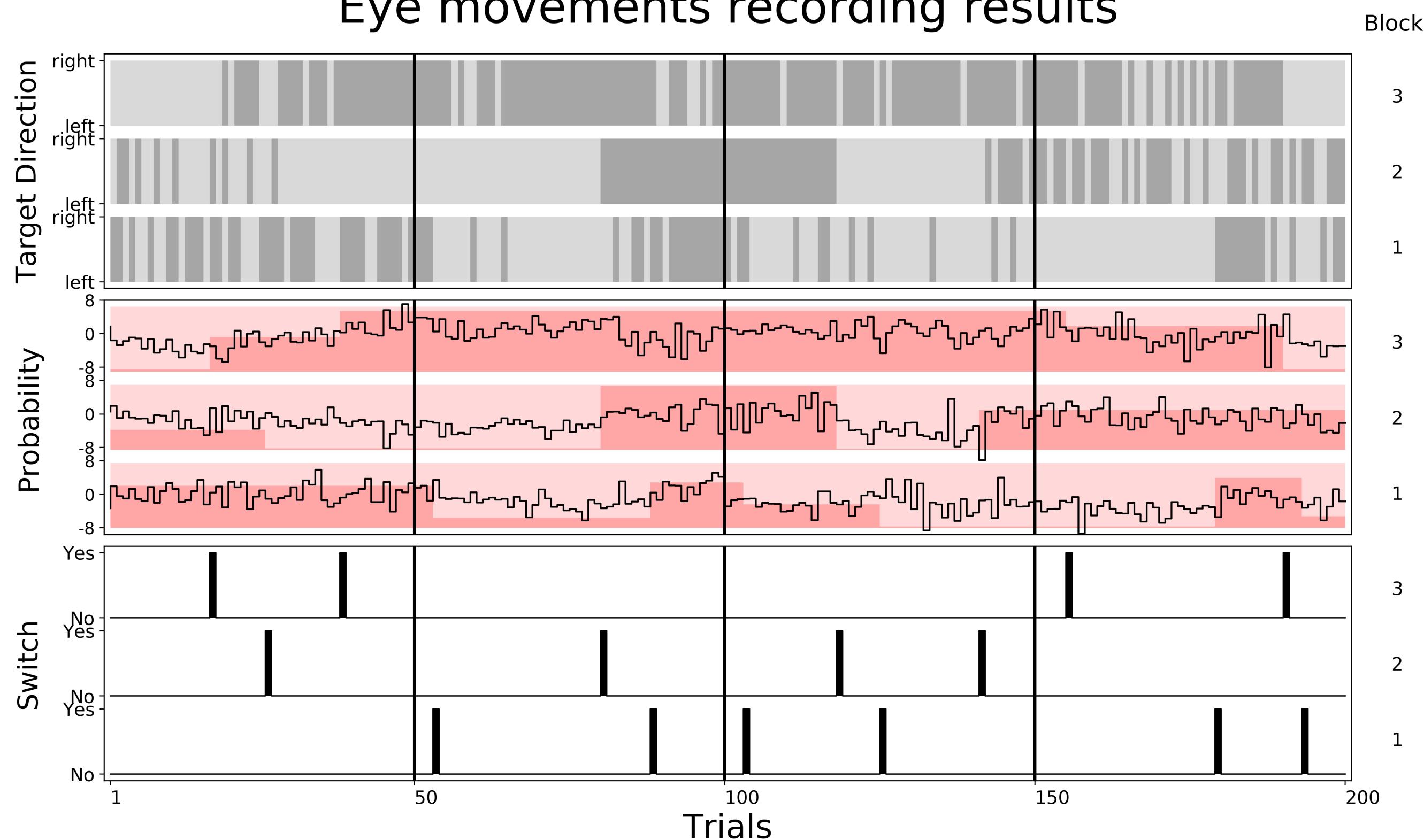
full code @ [github.com/chloepasturel/AnticipatorySPEM](https://github.com/chloepasturel/AnticipatorySPEM)

# Experimental protocol - Fitting eye movements



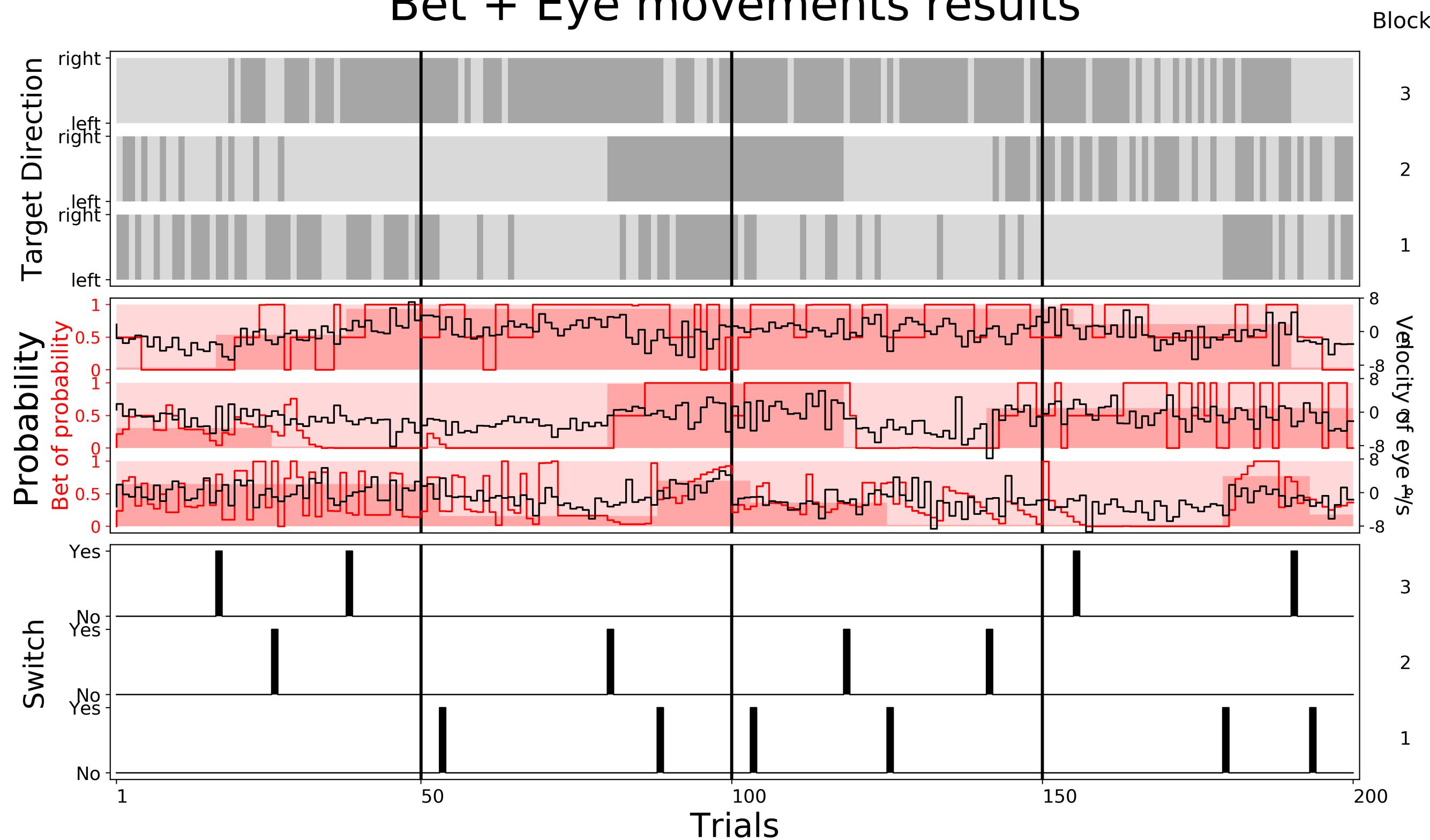
# Experimental protocol

## Eye movements recording results



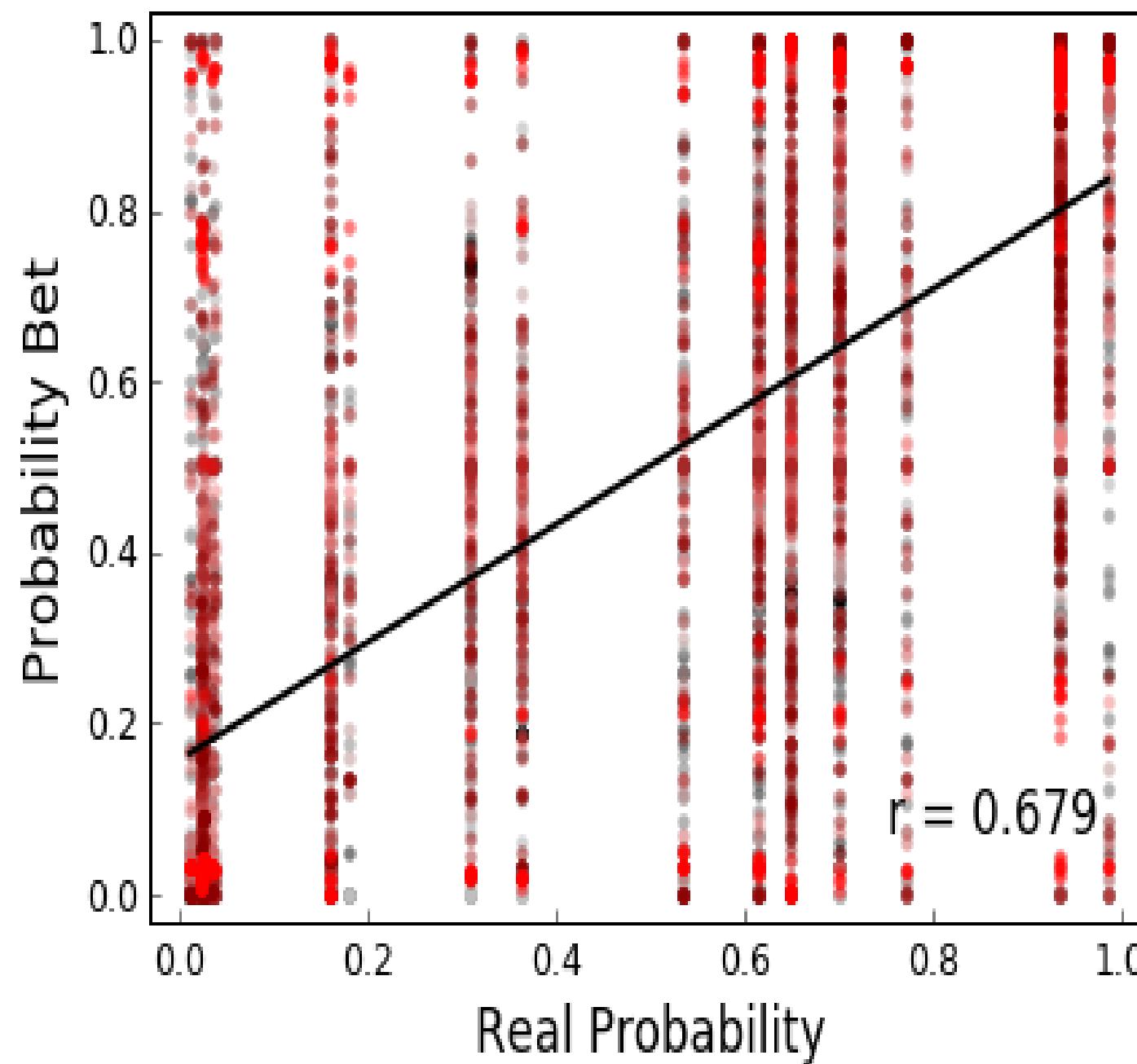
# Experimental protocol

## Bet + Eye movements results

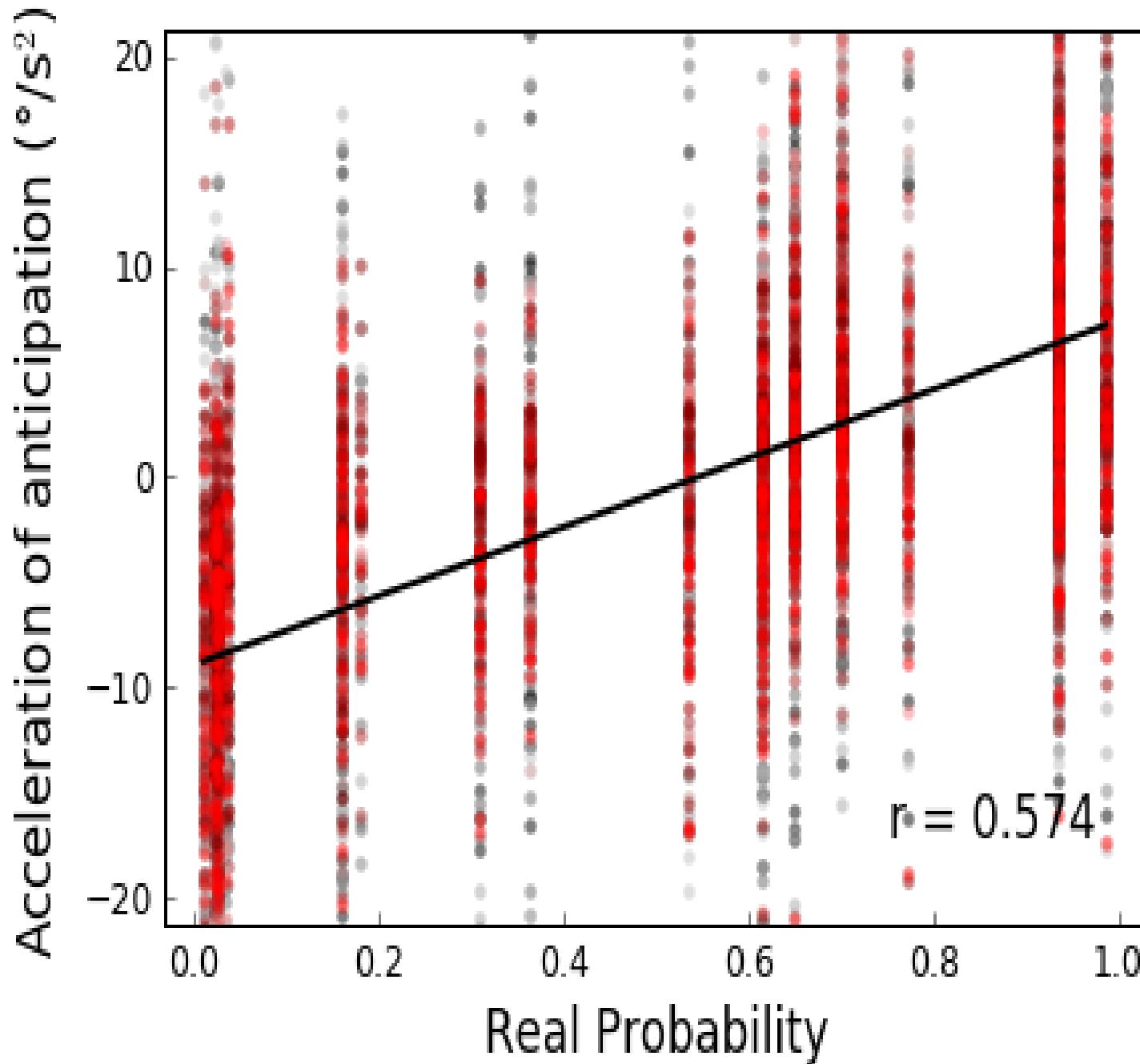


# Experimental protocol

Probability Bet



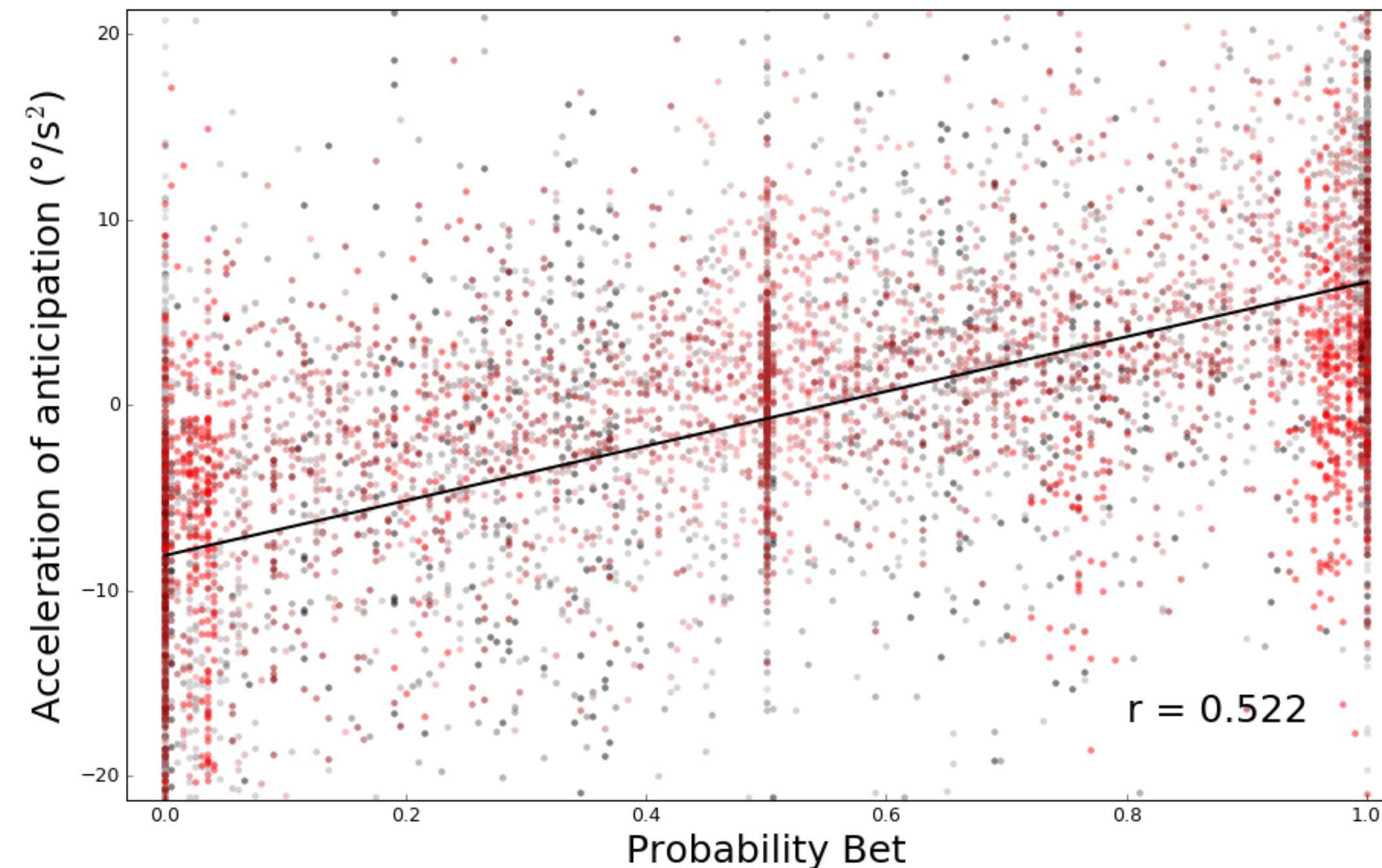
Acceleration



full code @ [github.com/chloepasturel/AnticipatorySPEM](https://github.com/chloepasturel/AnticipatorySPEM)

# Experimental protocol

Probability Bet vs Acceleration



full code @ [github.com/chloepasturel/AnticipatorySPEM](https://github.com/chloepasturel/AnticipatorySPEM)

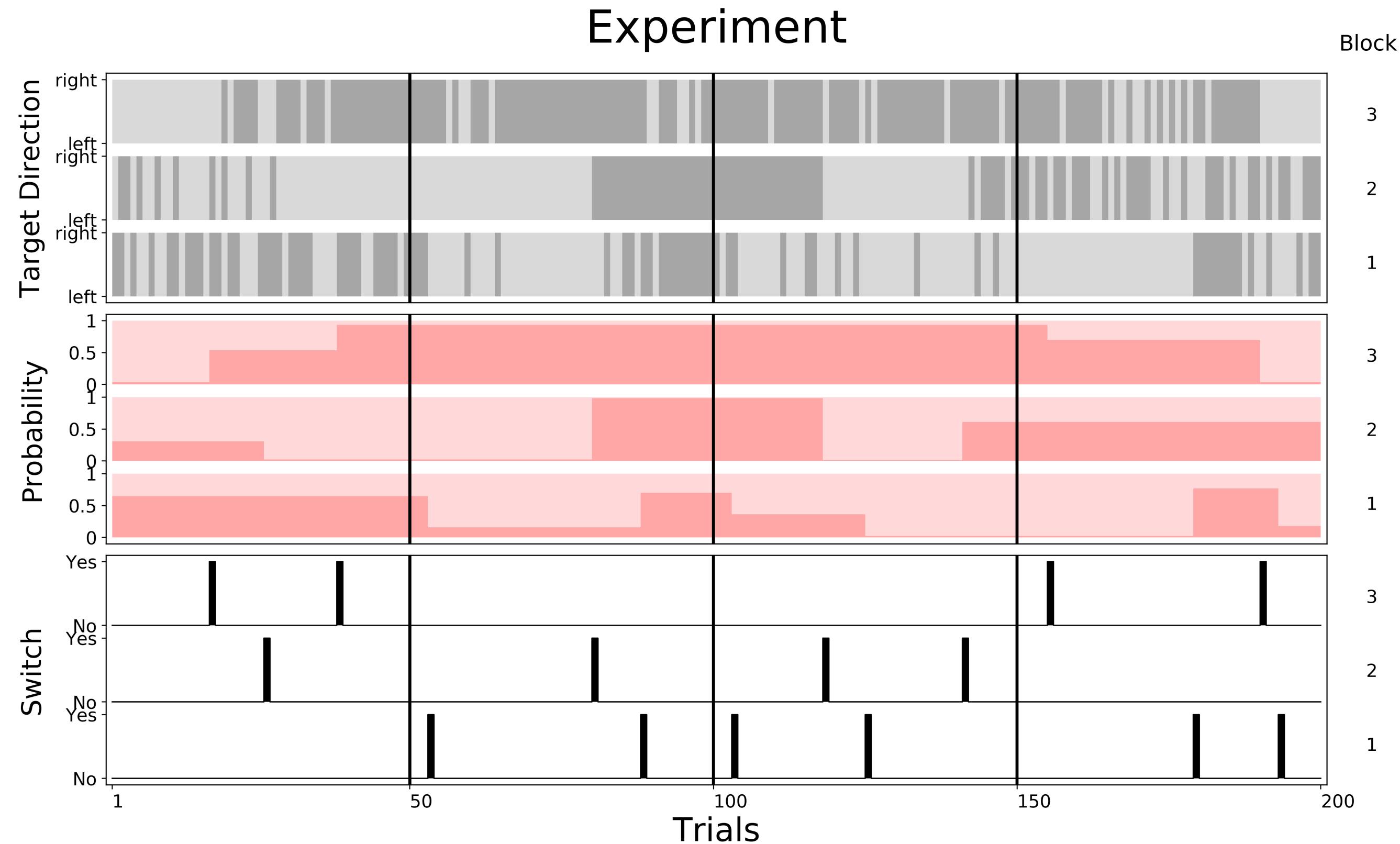
# Outline

1. Should I stay or should I go?
2. Experimental protocol
3. The Bayesian Changepoint Detector
4. Results using the BCP
5. Application to RL?

# Outline

1. Should I stay or should I go?
2. Experimental protocol
3. The Bayesian Changepoint Detector
4. Results using the BCP
5. Application to RL?

# The Bayesian Changepoint Detector - Random-length block design



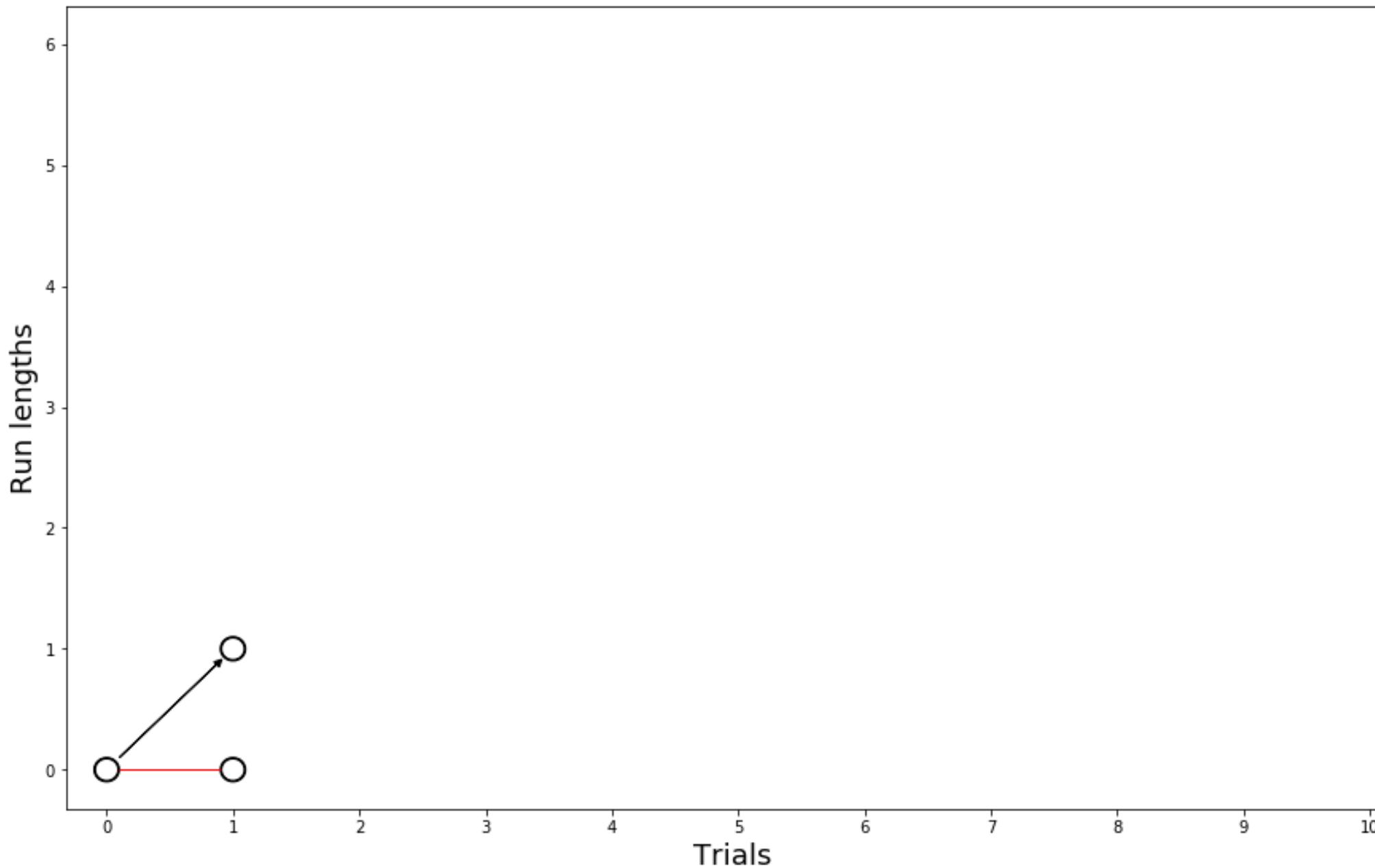
# Bayesian Online Changepoint Detector

- an implementation of Adams & MacKay 2007 "Bayesian Online Changepoint Detection" in Python.

```
@TECHREPORT{ adams-mackay-2007,
  AUTHOR = "Ryan Prescott Adams and David J.C. MacKay",
  TITLE  = "Bayesian Online Changepoint Detection",
  INSTITUTION = "University of Cambridge",
  ADDRESS = "Cambridge, UK",
  YEAR   = "2007",
  NOTE   = "arXiv:0710.3742v1 [stat.ML]",
  URL    = "http://arxiv.org/abs/0710.3742"
}
```

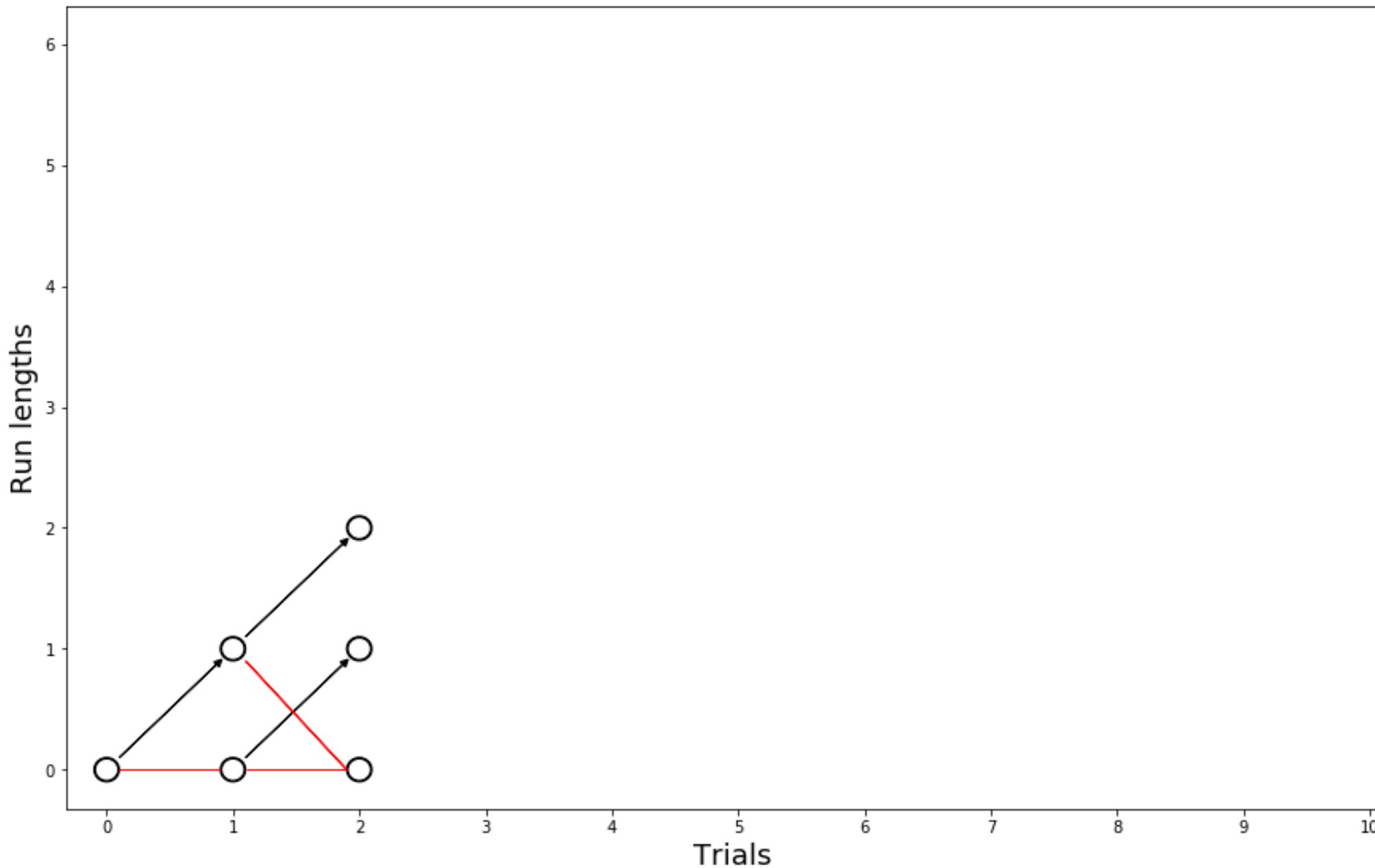
- adapted from <https://github.com/JackKelly/bayesianchangepoint> by Jack Kelly (2013) for a binomial input.
- This code is based on the MATLAB implementation provided by Ryan Adam. Was available at <http://hips.seas.harvard.edu/content/bayesian-online-changepoint-detection>
- full code @ <https://github.com/laurentperrinet/bayesianchangepoint>

# The Bayesian Changepoint Detector



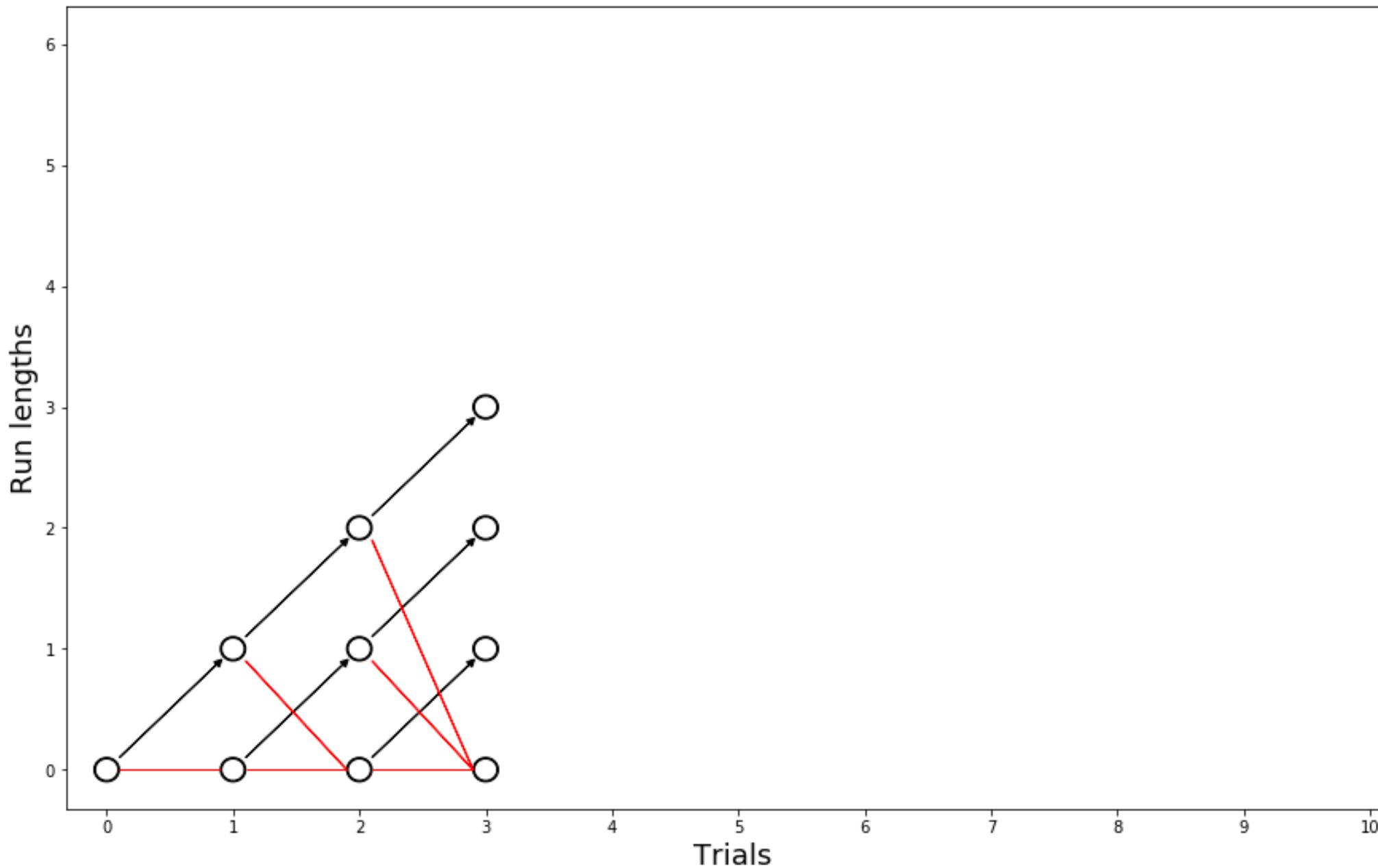
Initialize  $P(r_0=0)=1$  and  $v^{(0)}_1 = v_{\text{prior}}$  and  $\chi^{(0)}_1 = \chi_{\text{prior}}$

# The Bayesian Changepoint Detector



Observe New Datum  $x_{t+1}$  and Perform Prediction  $P(x_{t+1} | x_{1:t}) = P(x_{t+1}|x_{1:t}, r_t) \cdot P(r_t|x_{1:t})$

# The Bayesian Changepoint Detector



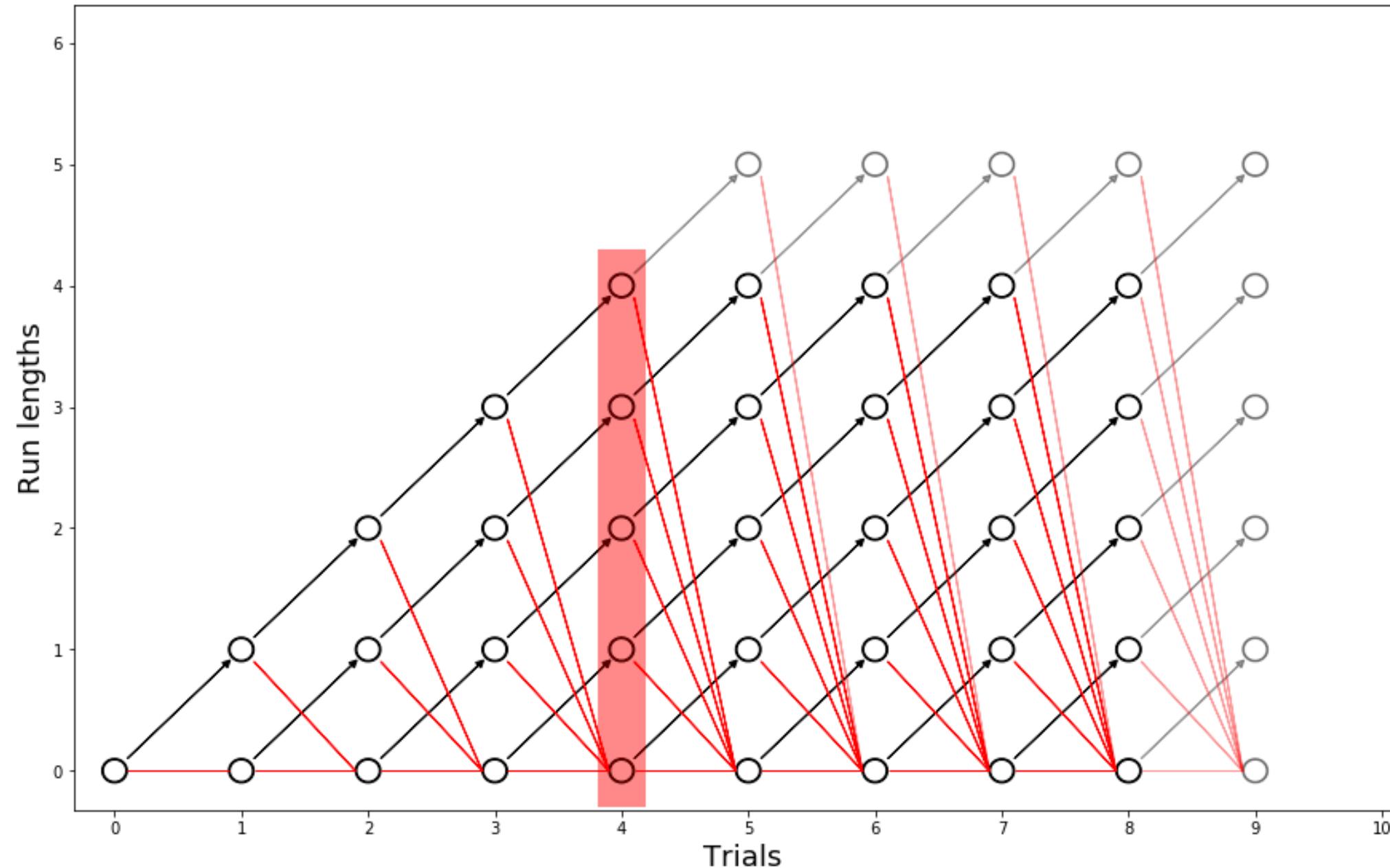
Evaluate (likelihood) Predictive Probability  $\pi_{1:t} = P(x_t | v^{(r)}_t, \chi^{(r)}_t)$

Calculate Growth Probabilities  $P(r_t=r_{t-1}+1, x_{1:t}) = P(r_{t-1}, x_{1:t-1}) \cdot \pi^{(r)}_t$

$$\cdot (1-h)$$

Calculate Changepoint Probabilities  $P(r_{t=0}, x_{1:t}) = \sum_{r_{t-1}} P(r_{t-1}, x_{1:t-1}) \cdot \pi^{(r)}_t \cdot h$

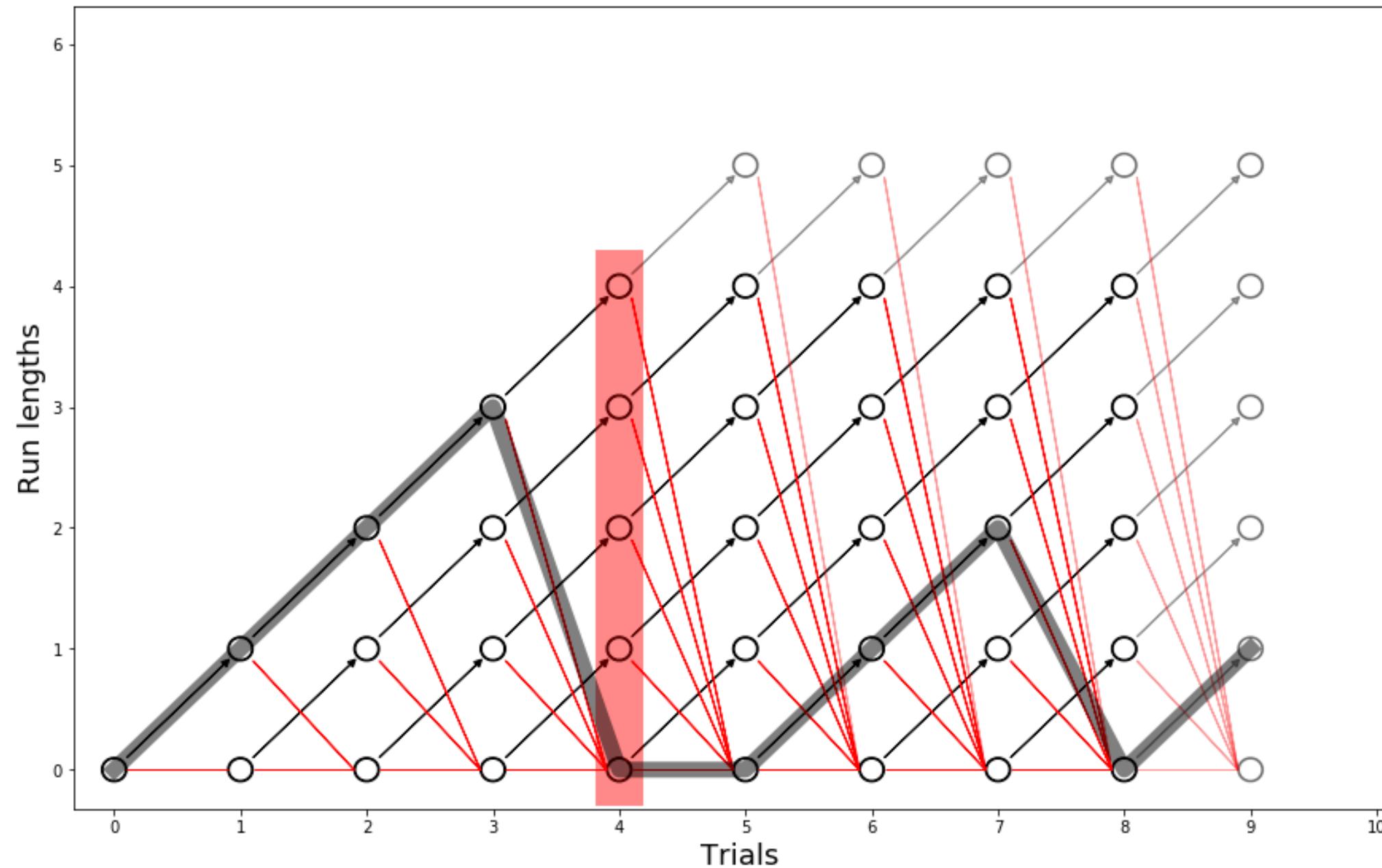
# The Bayesian Changepoint Detector



Calculate Evidence  $P(x_{1:t}) = \sum_{r_{t-1}} P(r_t, x_{1:t})$

Determine Run Length Distribution  $P(r_t | x_{1:t}) = P(r_t, x_{1:t}) / P(x_{1:t})$

# The Bayesian Changepoint Detector



Update Sufficient Statistics :

$$v^{(r+1)}_{t+1} = v^{(r)}_t + 1, \quad x^{(r+1)}_{t+1} = x^{(r)}_t + u(x_t)$$

# Bayesian Changepoint Detector

## 1. Initialize

- $P(r_0=0)=1$  and
- $v^{(0)}_1 = v_{\text{prior}}$  and  $x^{(0)}_1 = x_{\text{prior}}$

## 2. Observe New Datum $x_t$

## 3. Evaluate Predictive Probability $\pi_{1:t} = P(x_t | v^{(r)}_t, x^{(r)}_t)$

## 4. Calculate Growth Probabilities $P(r_t=r_{t-1}+1, x_{1:t}) = P(r_{t-1}, x_{1:t-1}) \cdot \pi^{(r)}_t \cdot (1 - H(r^{(r)}_{t-1}))$

## 5. Calculate Changepoint Probabilities $P(r_t=0, x_{1:t}) = \sum_{r_{t-1}} P(r_{t-1}, x_{1:t-1}) \cdot \pi^{(r)}_t \cdot H(r^{(r)}_{t-1})$

## 6. Calculate Evidence $P(x_{1:t}) = \sum_{r_{t-1}} P(r_t, x_{1:t})$

## 7. Determine Run Length Distribution $P(r_t | x_{1:t}) = P(r_t, x_{1:t}) / P(x_{1:t})$

## 8. Update Sufficient Statistics :

- $v^{(0)}_{t+1} = v_{\text{prior}}$ ,  $x^{(0)}_{t+1} = x_{\text{prior}}$
- $v^{(r+1)}_{t+1} = v^{(r)}_t + 1$ ,  $x^{(r+1)}_{t+1} = x^{(r)}_t + u(x_t)$

## 9. Perform Prediction $P(x_{t+1} | x_{1:t}) = P(x_{t+1} | x_{1:t}, r_t) \cdot P(r_t | x_{1:t})$

## 10. go to (2)

# The Bayesian Changepoint Detector

The screenshot shows the GitHub repository page for 'laurentperrinet/bayesianchangepoint'. The repository is a fork from 'JackKelly/bayesianchangepoint'. It has 20 commits, 1 branch, 0 releases, and 3 contributors. The latest commit was on Oct 27, 2017. The repository description is: "An implementation of Adams & MacKay 2007 "Bayesian Online Changepoint Detection"".

Key statistics:

- 20 commits
- 1 branch
- 0 releases
- 3 contributors

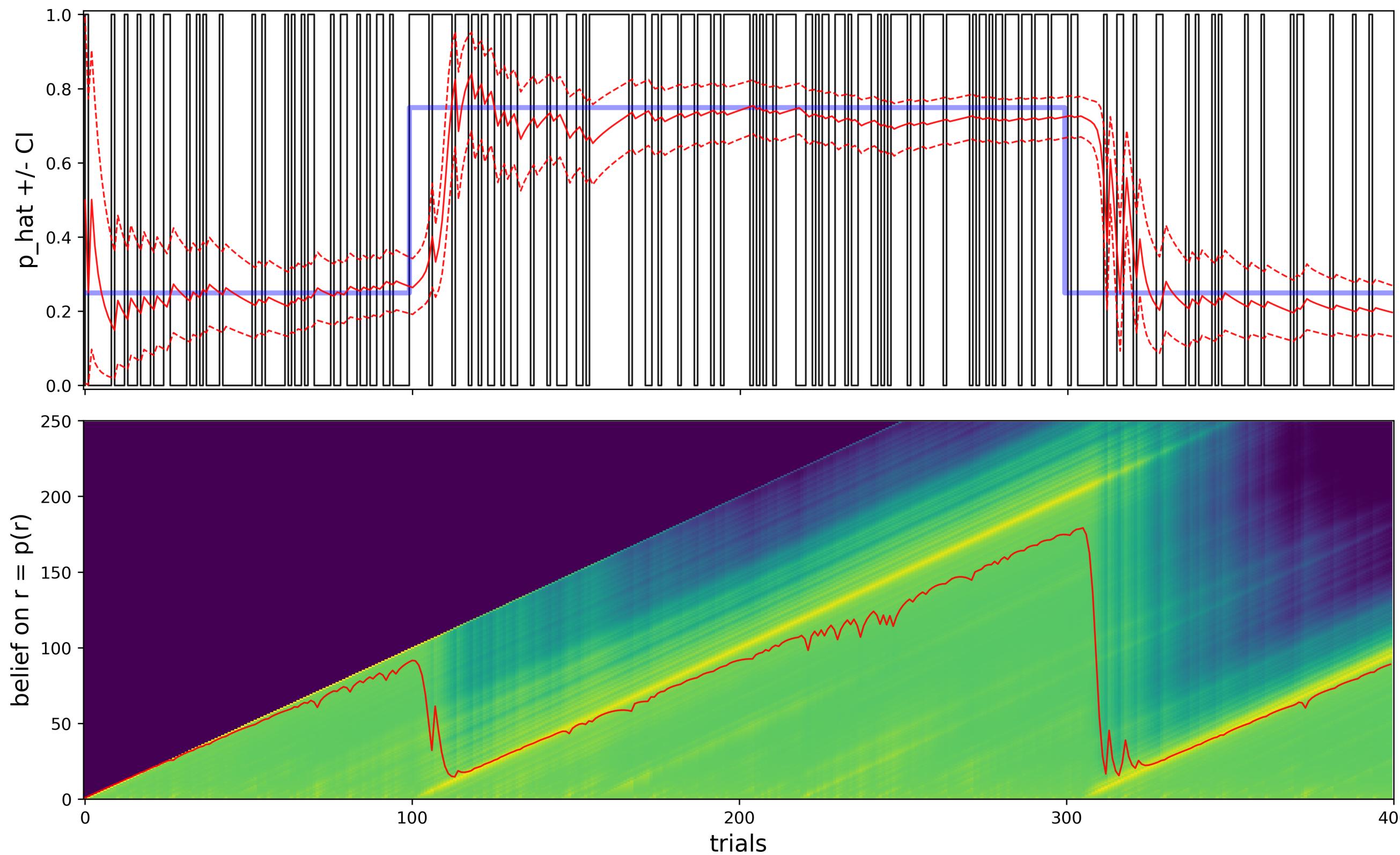
Branch: master | New pull request | Create new file | Upload files | Find file | Clone or download

This branch is 11 commits ahead of JackKelly:master.

File	Commit Message	Date
bayesianchangepoint	testing scoring method with the likelihood to find an optimal hazard...	Oct 26, 2017
notebooks	testing scoring method with the likelihood to find an optimal hazard...	Oct 27, 2017
.gitignore	small fixes	Oct 26, 2017
LICENSE	Initial commit	Oct 23, 2013
README.md	importing functions from notebook	Oct 26, 2017
setup.py	small fixes	Oct 26, 2017

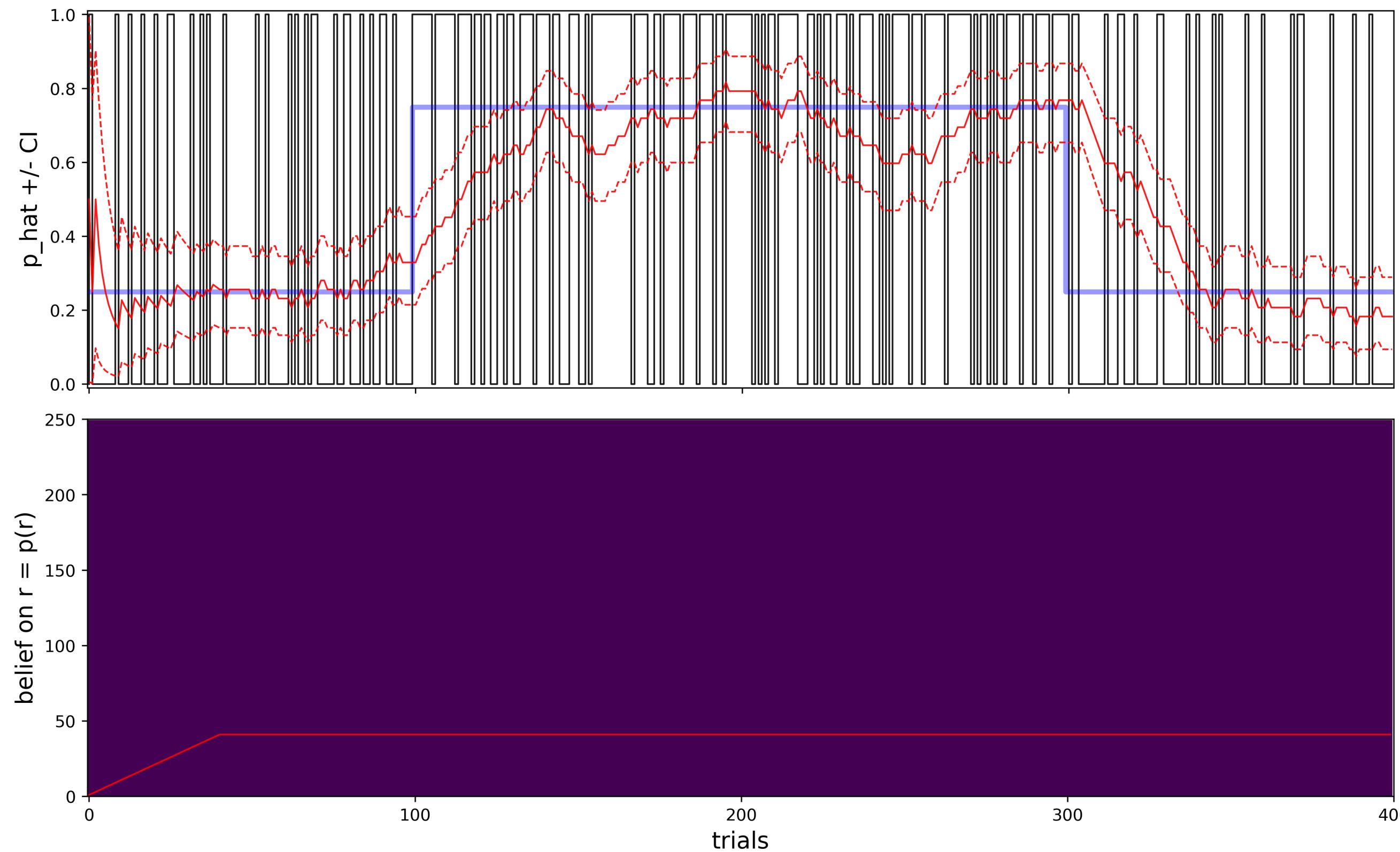
full code @ [github.com/laurentperrinet/bayesianchangepoint](https://github.com/laurentperrinet/bayesianchangepoint)

# The Bayesian Changepoint Detector - Full model



full code @ [github.com/laurentperrinet/bayesianchangepoint](https://github.com/laurentperrinet/bayesianchangepoint)

# The Bayesian Changepoint Detector - Fixed window



full code @ [github.com/laurentperrinet/bayesianchangepoint](https://github.com/laurentperrinet/bayesianchangepoint)

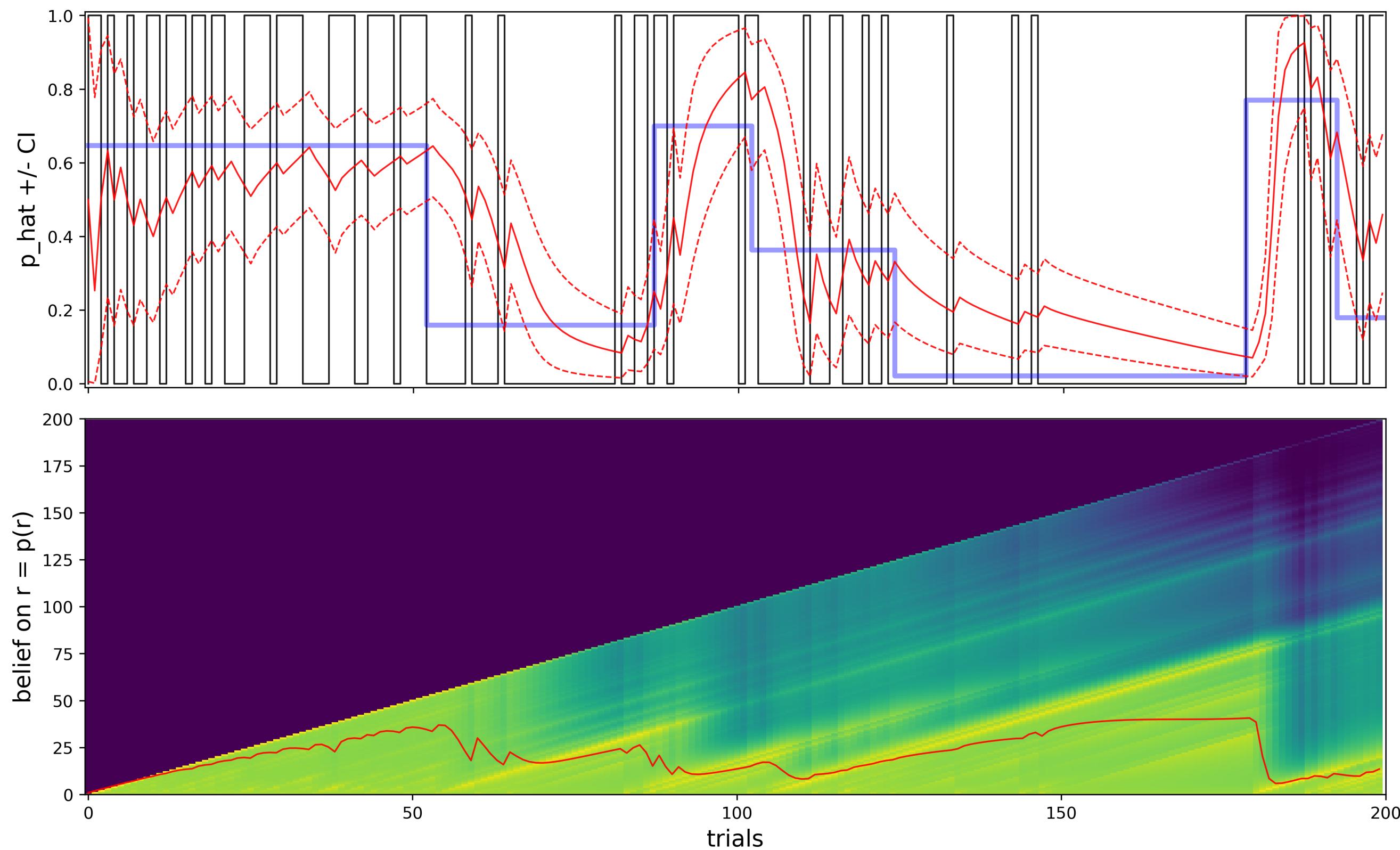
# Outline

1. Should I stay or should I go?
2. Experimental protocol
3. The Bayesian Changepoint Detector
4. Results using the BCP
5. Application to RL?

# Outline

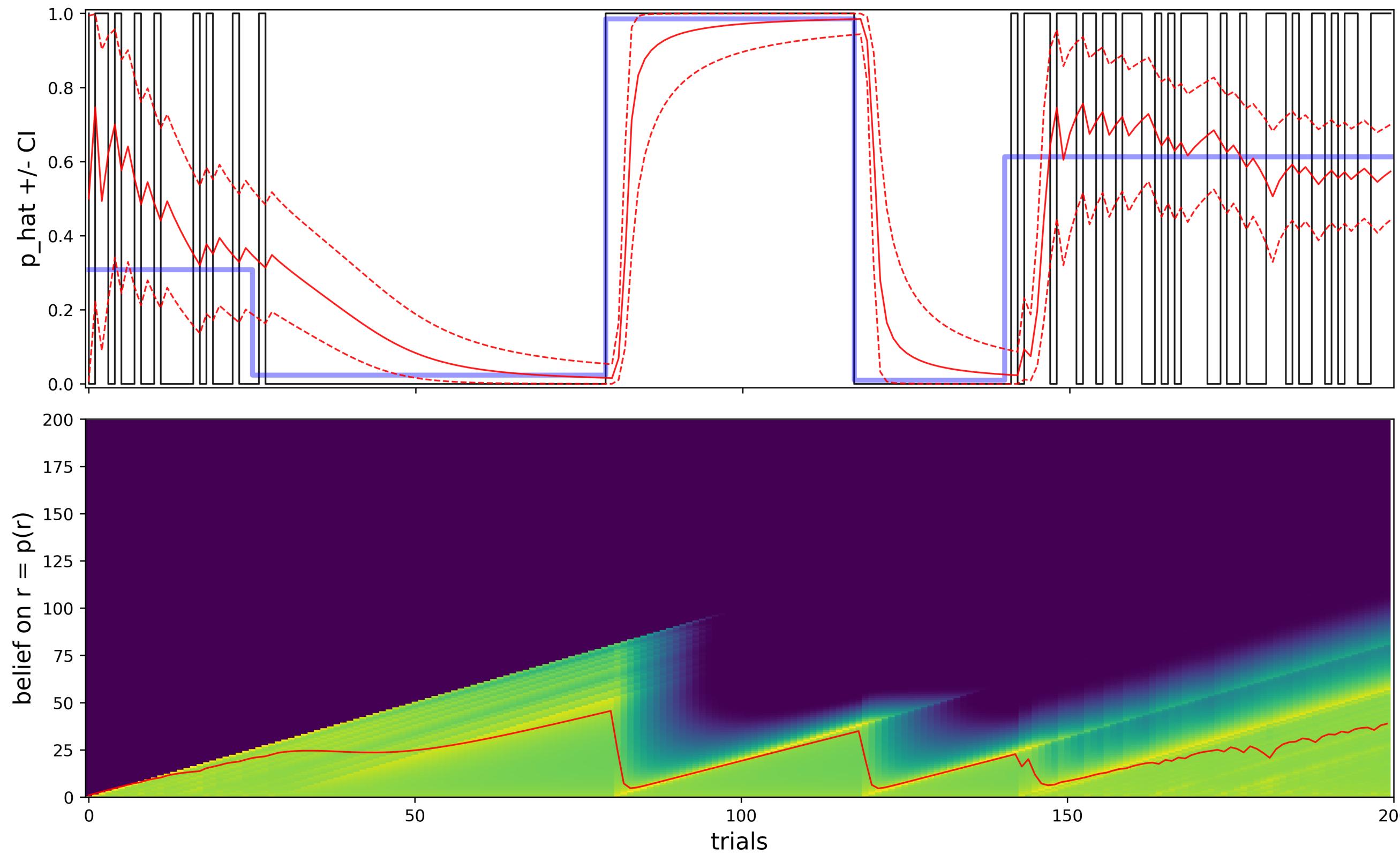
1. Should I stay or should I go?
2. Experimental protocol
3. The Bayesian Changepoint Detector
4. Results using the BCP
5. Application to RL?

# Results using the BCP - Full model



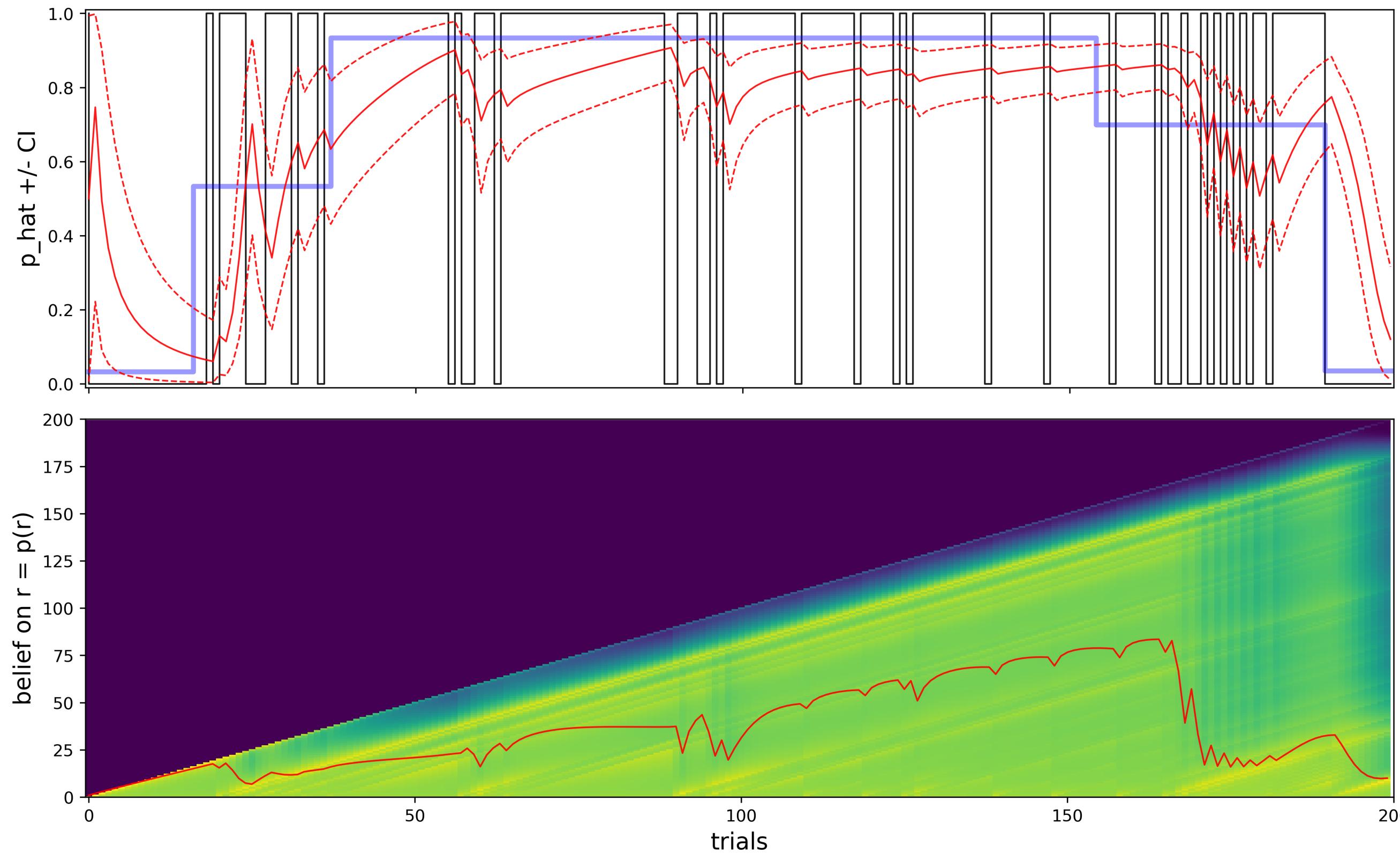
full code @ [github.com/laurentperrinet/bayesianchangepoint](https://github.com/laurentperrinet/bayesianchangepoint)

# Results using the BCP - Full model



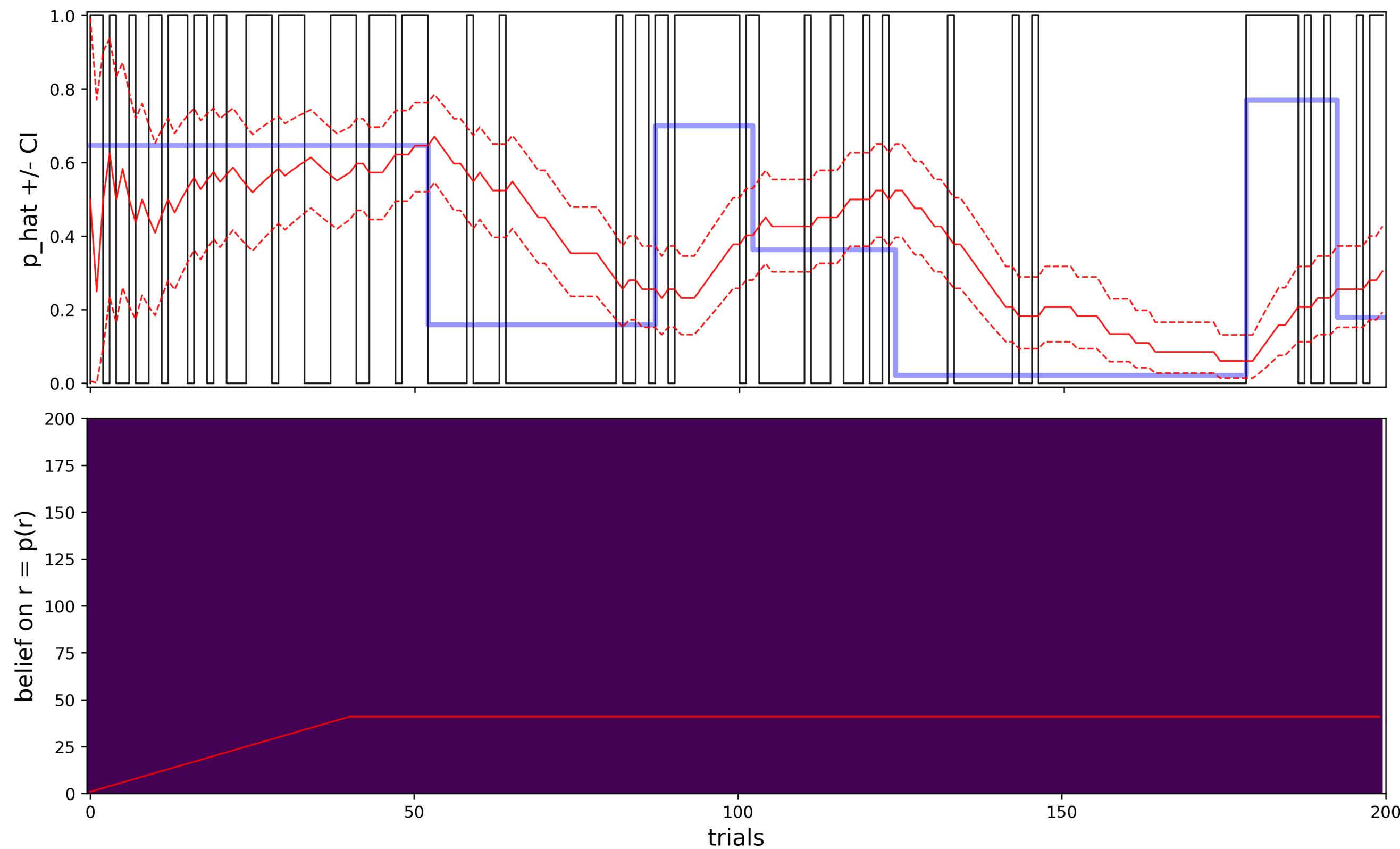
full code @ [github.com/laurentperrinet/bayesianchangepoint](https://github.com/laurentperrinet/bayesianchangepoint)

# Results using the BCP - Full model



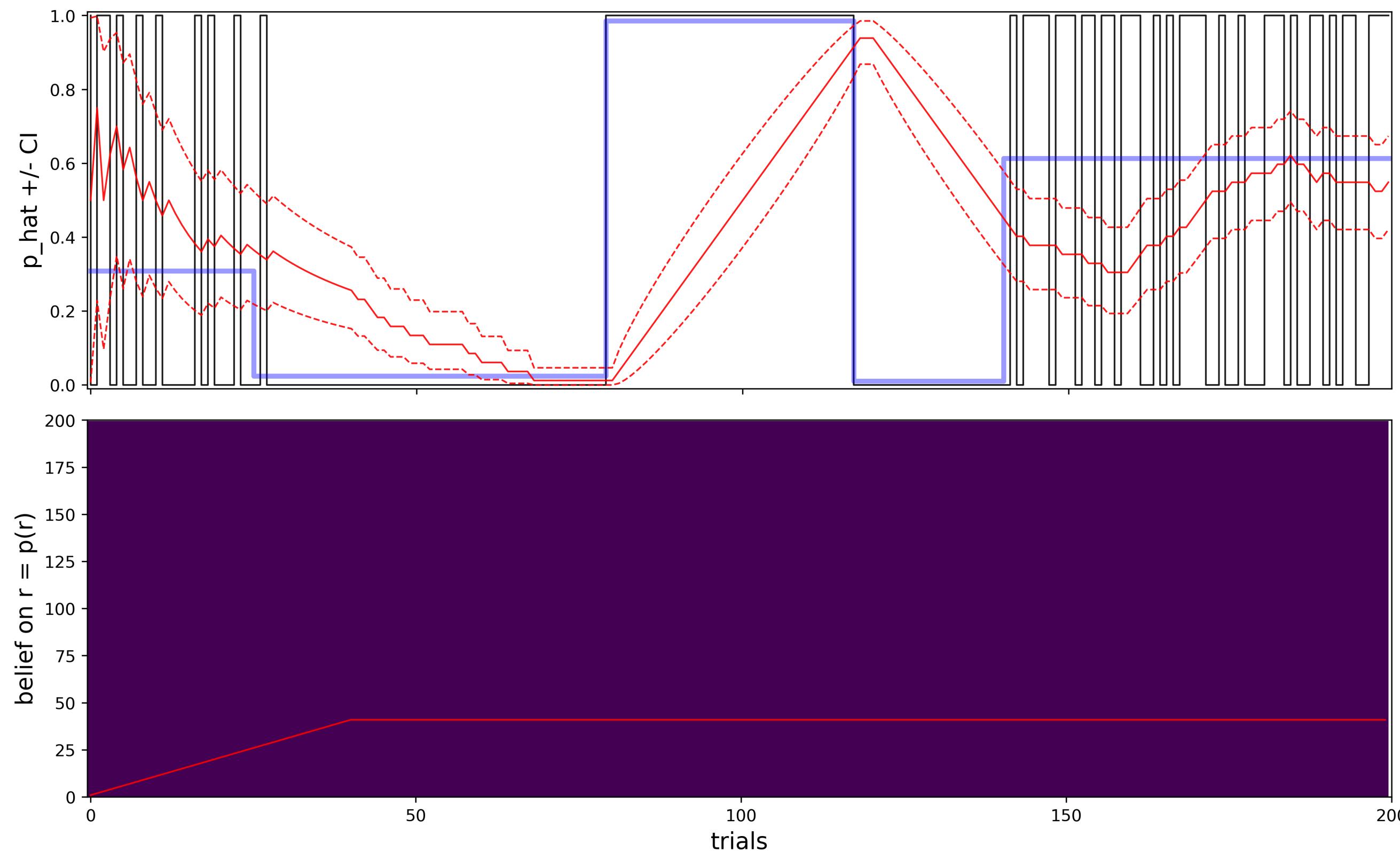
full code @ [github.com/laurentperrinet/bayesianchangepoint](https://github.com/laurentperrinet/bayesianchangepoint)

# Results using the BCP - Fixed window



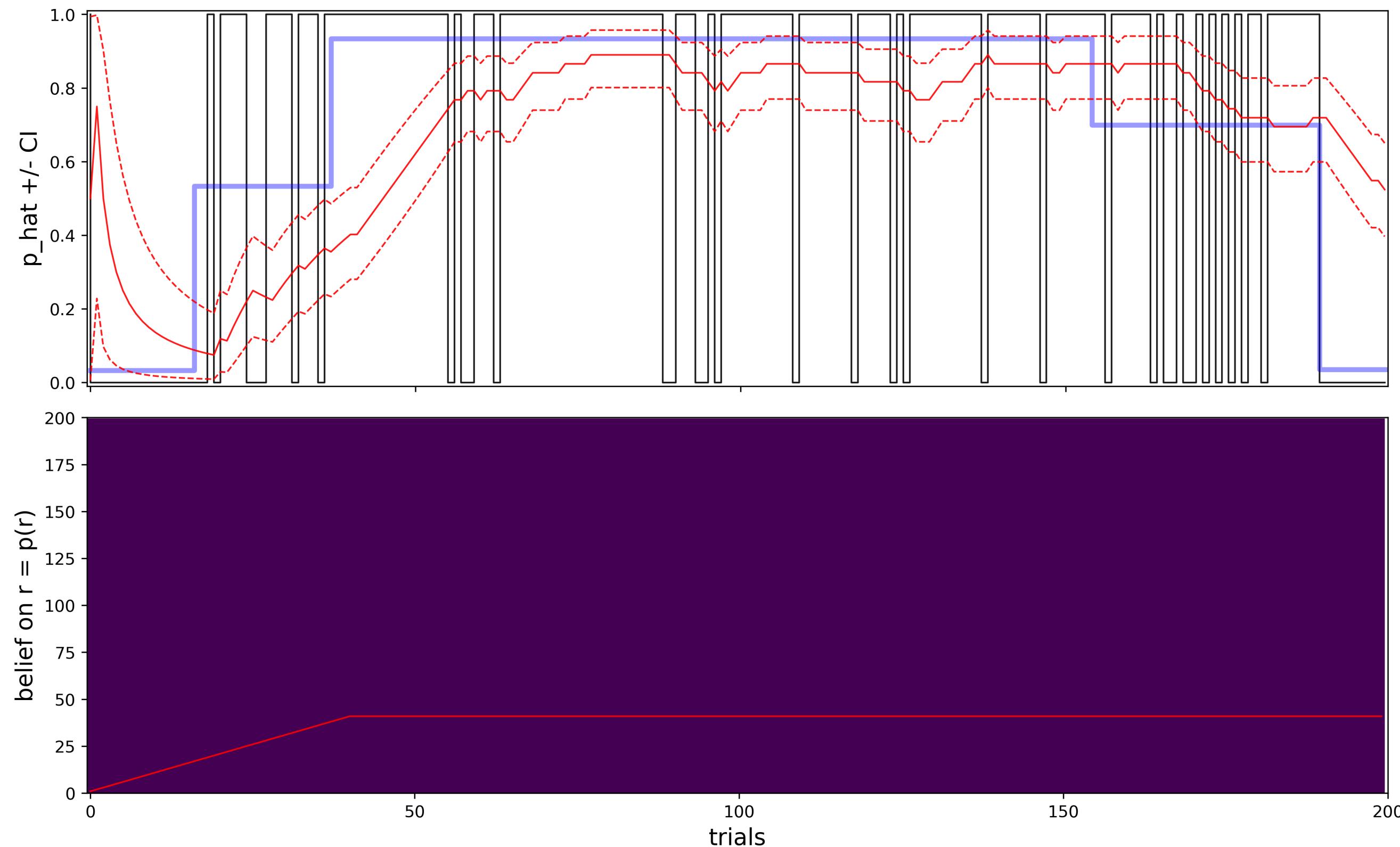
full code @ [github.com/laurentperrinet/bayesianchangepoint](https://github.com/laurentperrinet/bayesianchangepoint)

# Results using the BCP - Fixed window

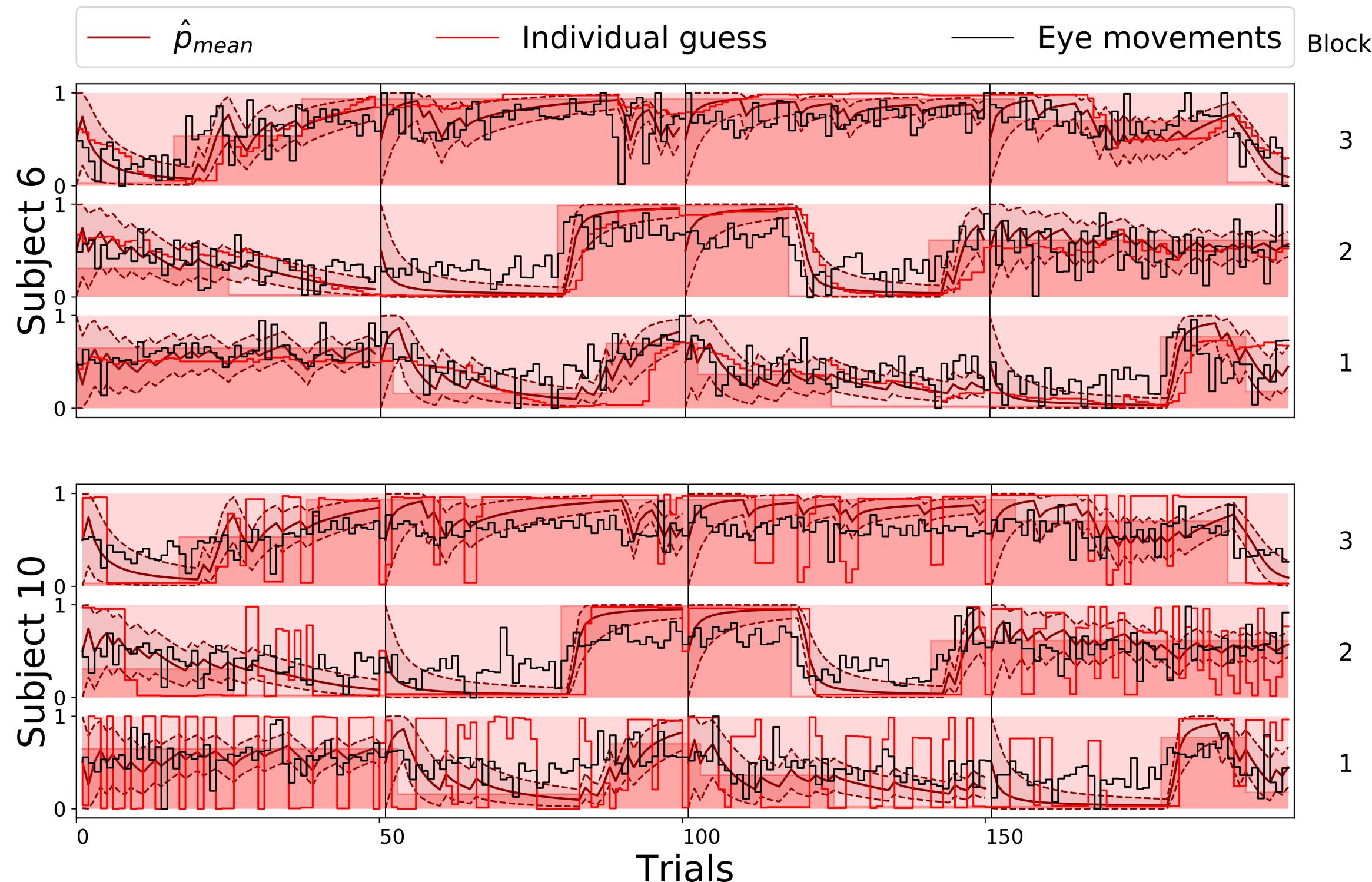


full code @ [github.com/laurentperrinet/bayesianchangepoint](https://github.com/laurentperrinet/bayesianchangepoint)

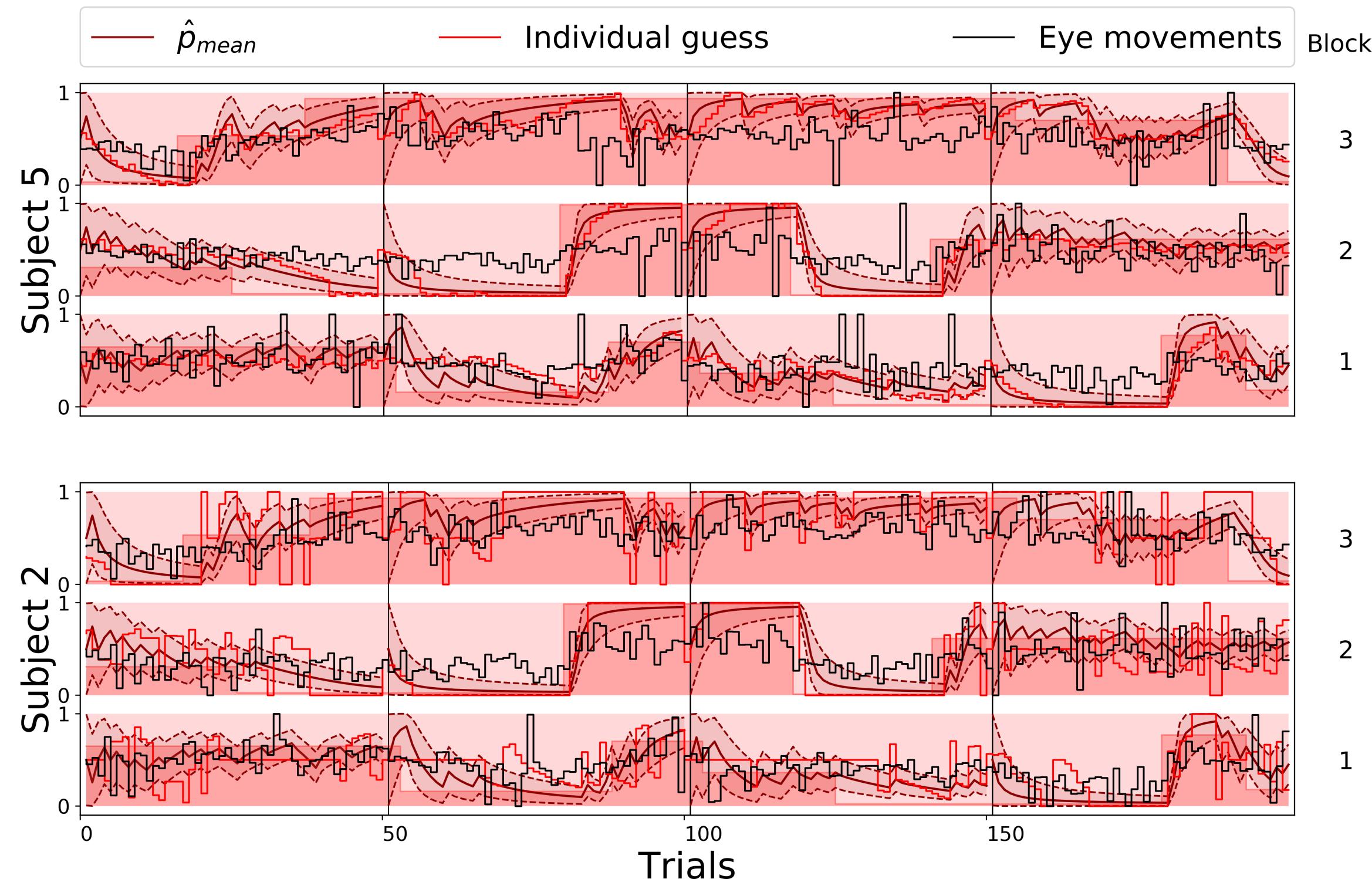
# Results using the BCP - Fixed window



# Results using the BCP - fit with BCP

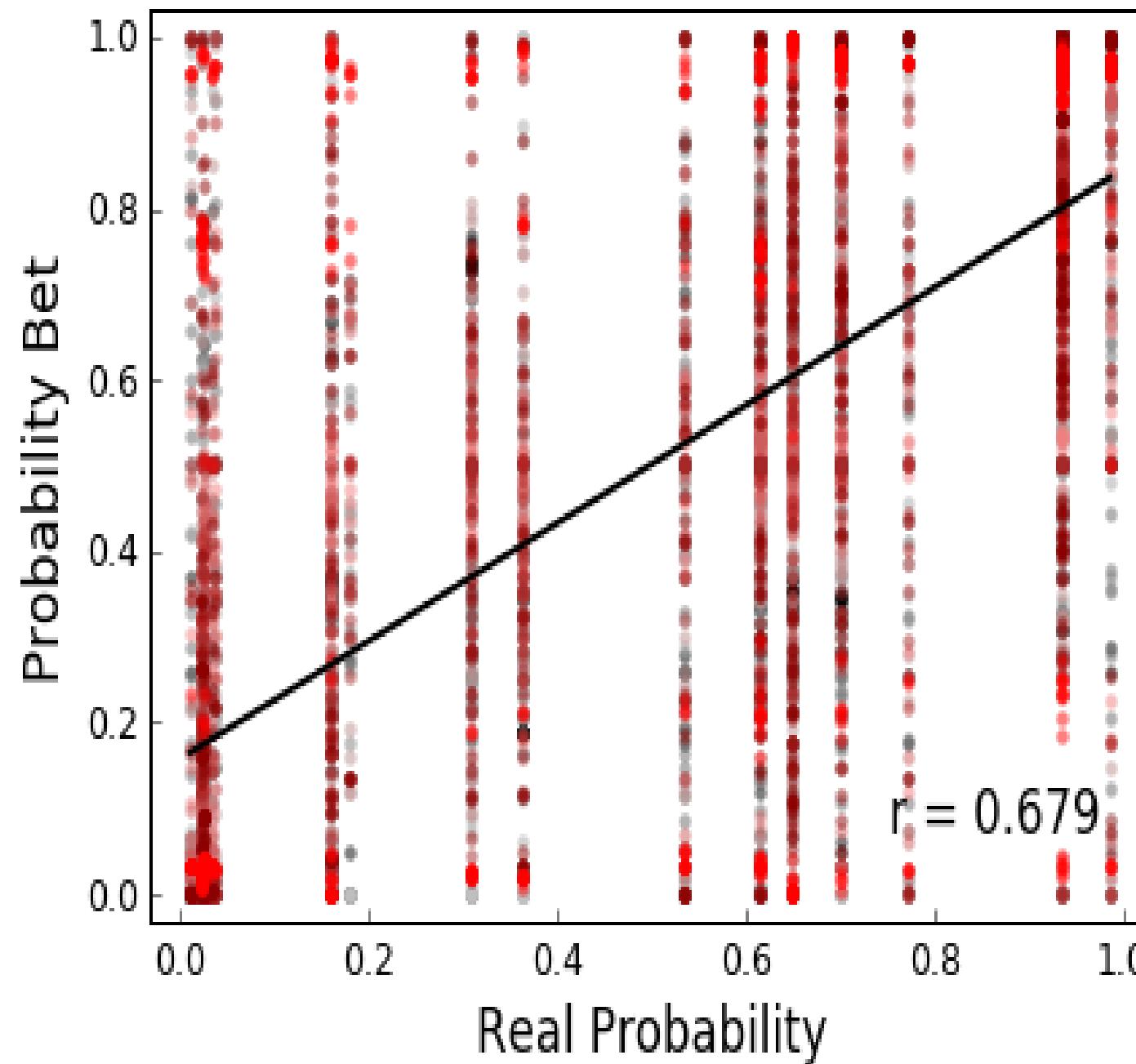


# Results using the BCP - fit with BCP

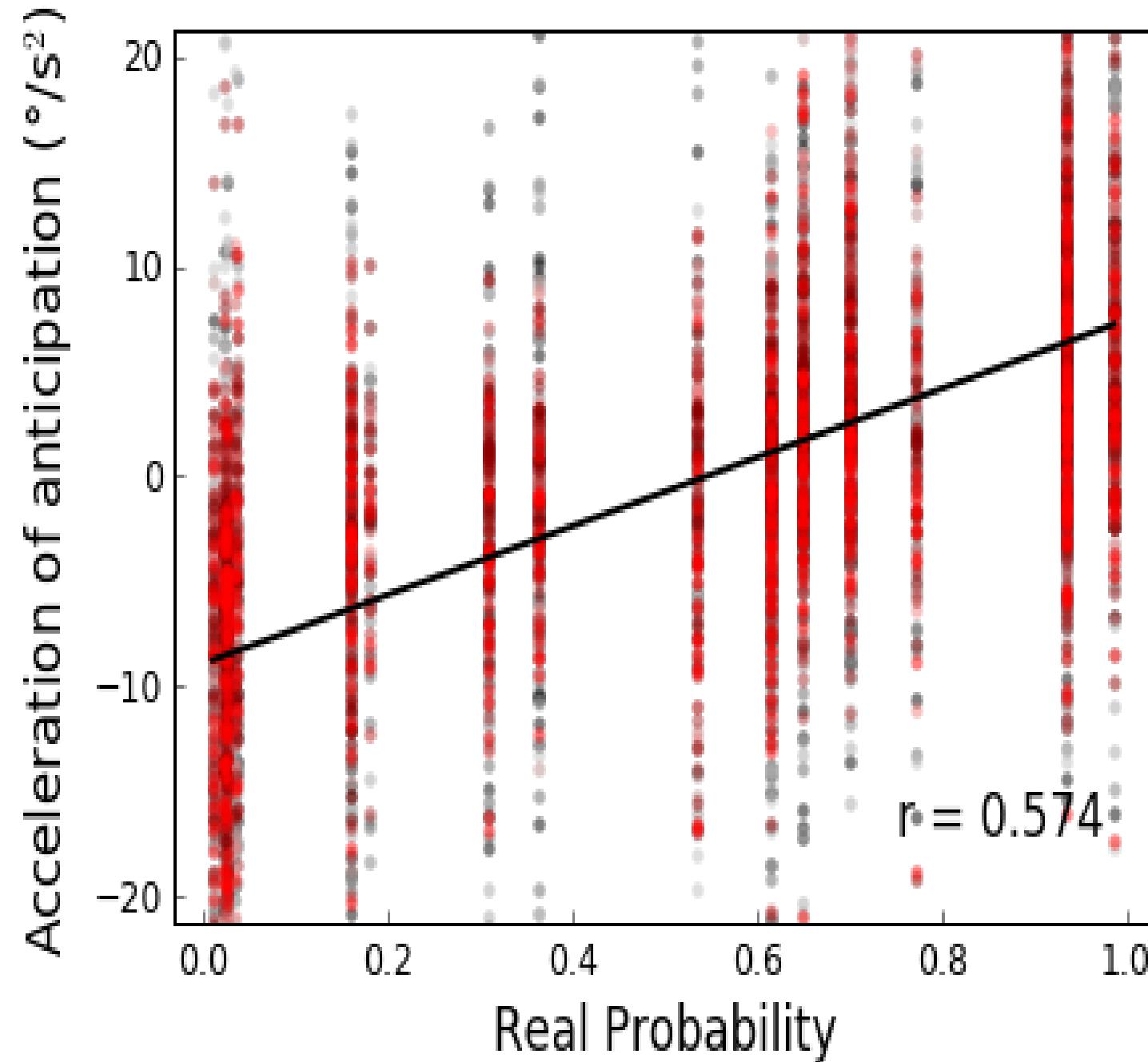


# Results using the BCP

Probability Bet



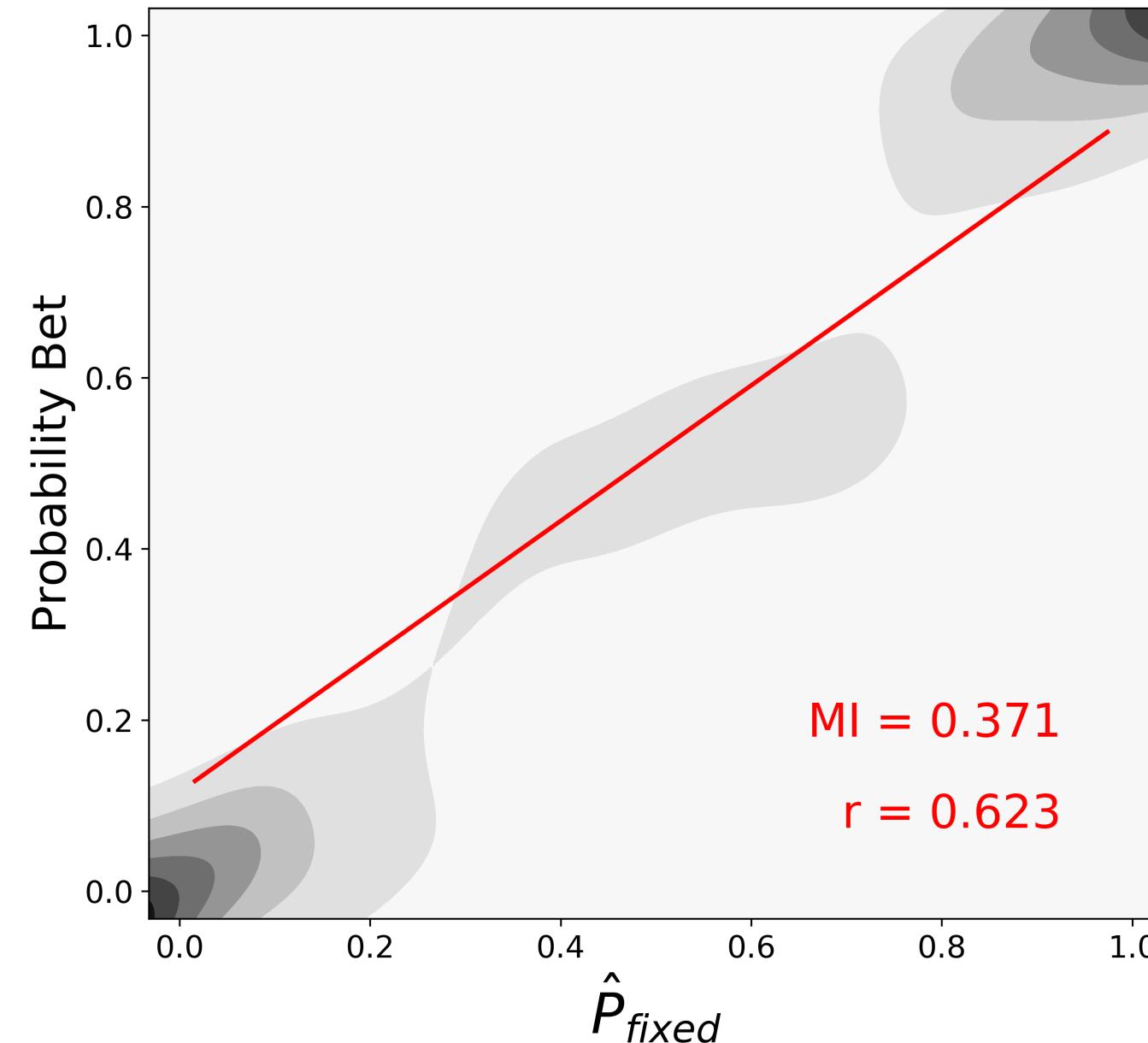
Acceleration



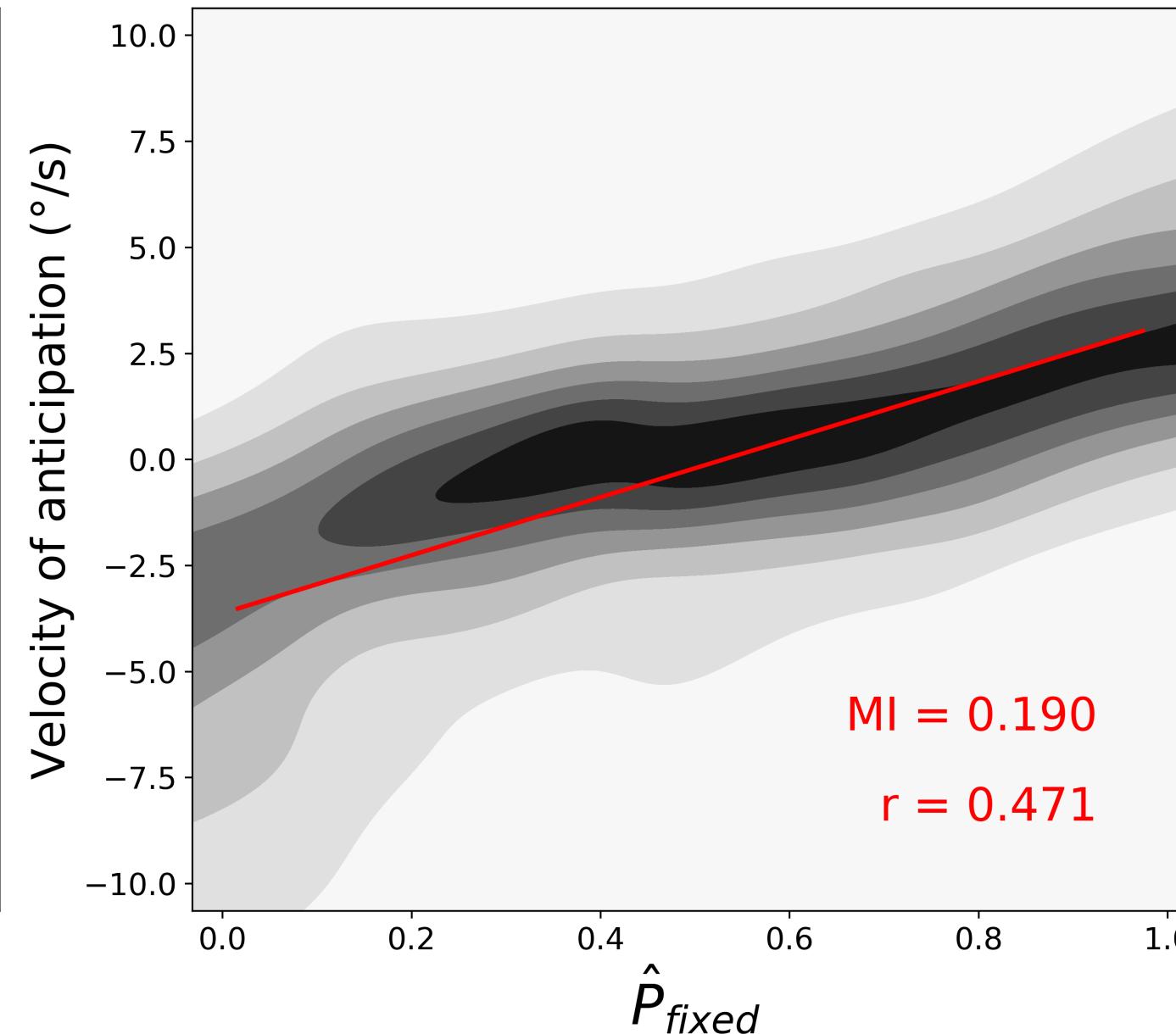
full code @ [github.com/laurentperrinet/bayesianchangepoint](https://github.com/laurentperrinet/bayesianchangepoint)

# Results using the BCP - Fixed window

Probability Bet

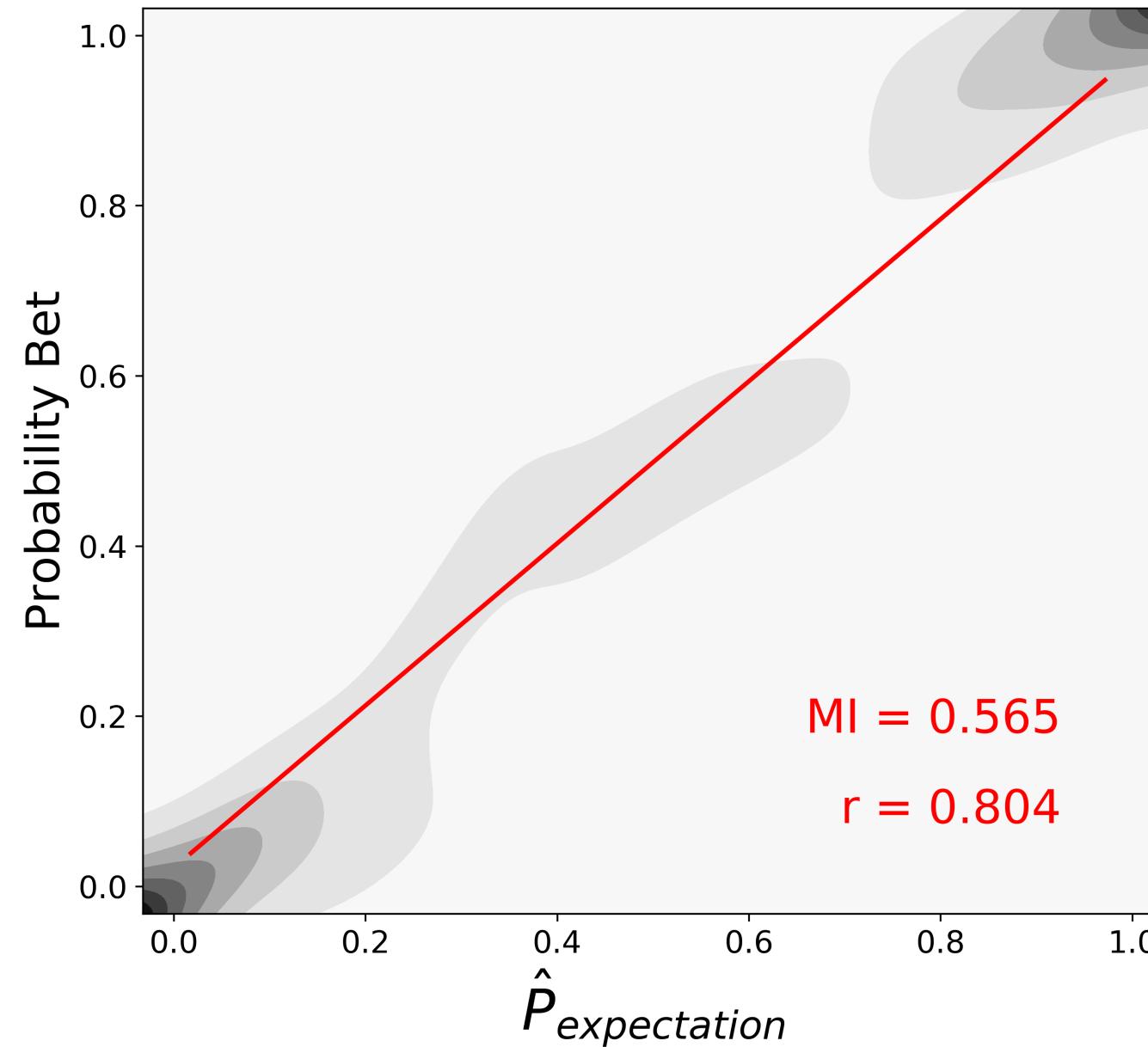


Velocity

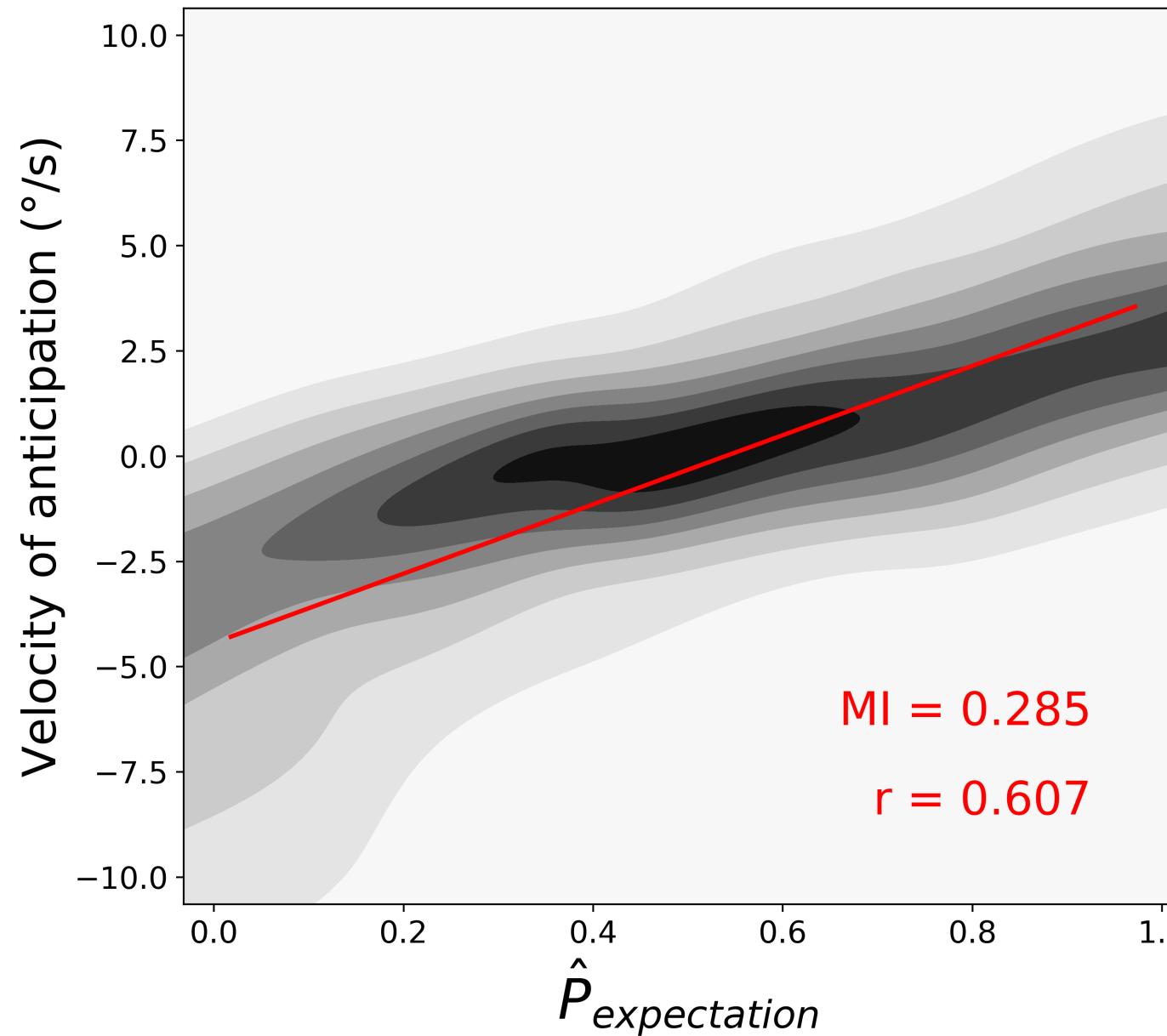


# Results using the BCP - Full model

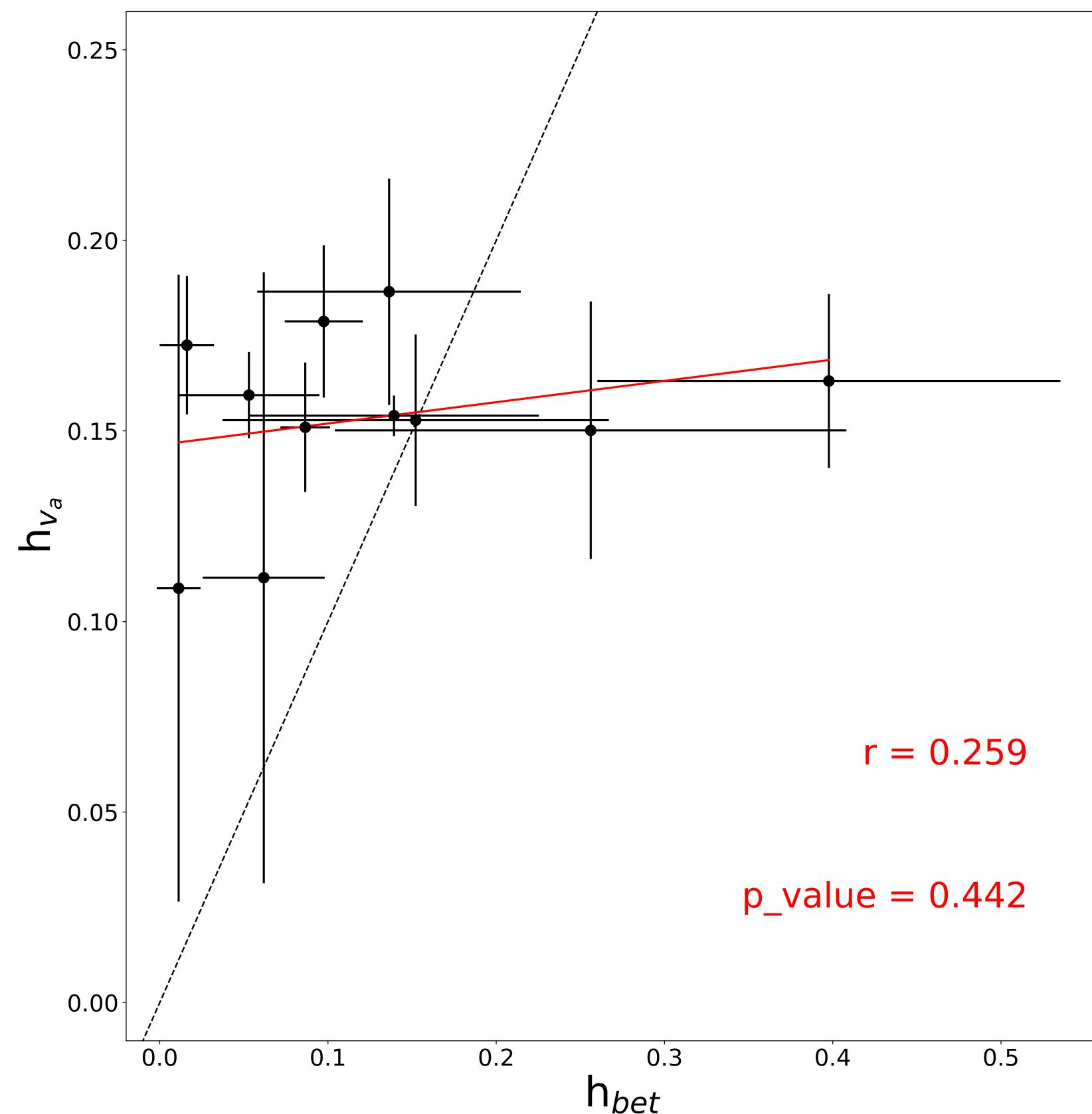
Probability Bet



Velocity



# Results using the BCPinterindividual differences



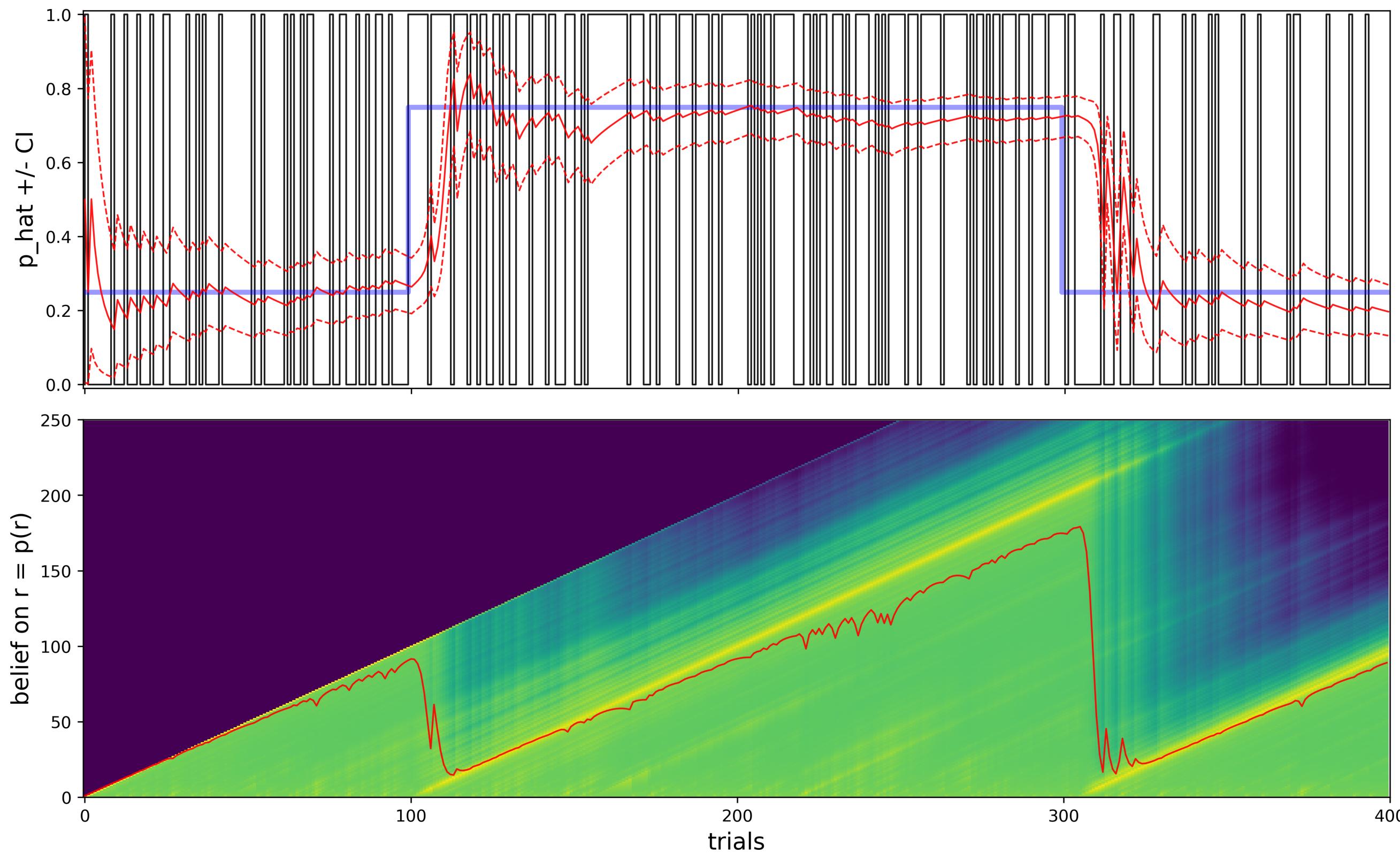
# Outline

1. Should I stay or should I go?
2. Experimental protocol
3. The Bayesian Changepoint Detector
4. Results using the BCP
5. Application to RL?

# Outline

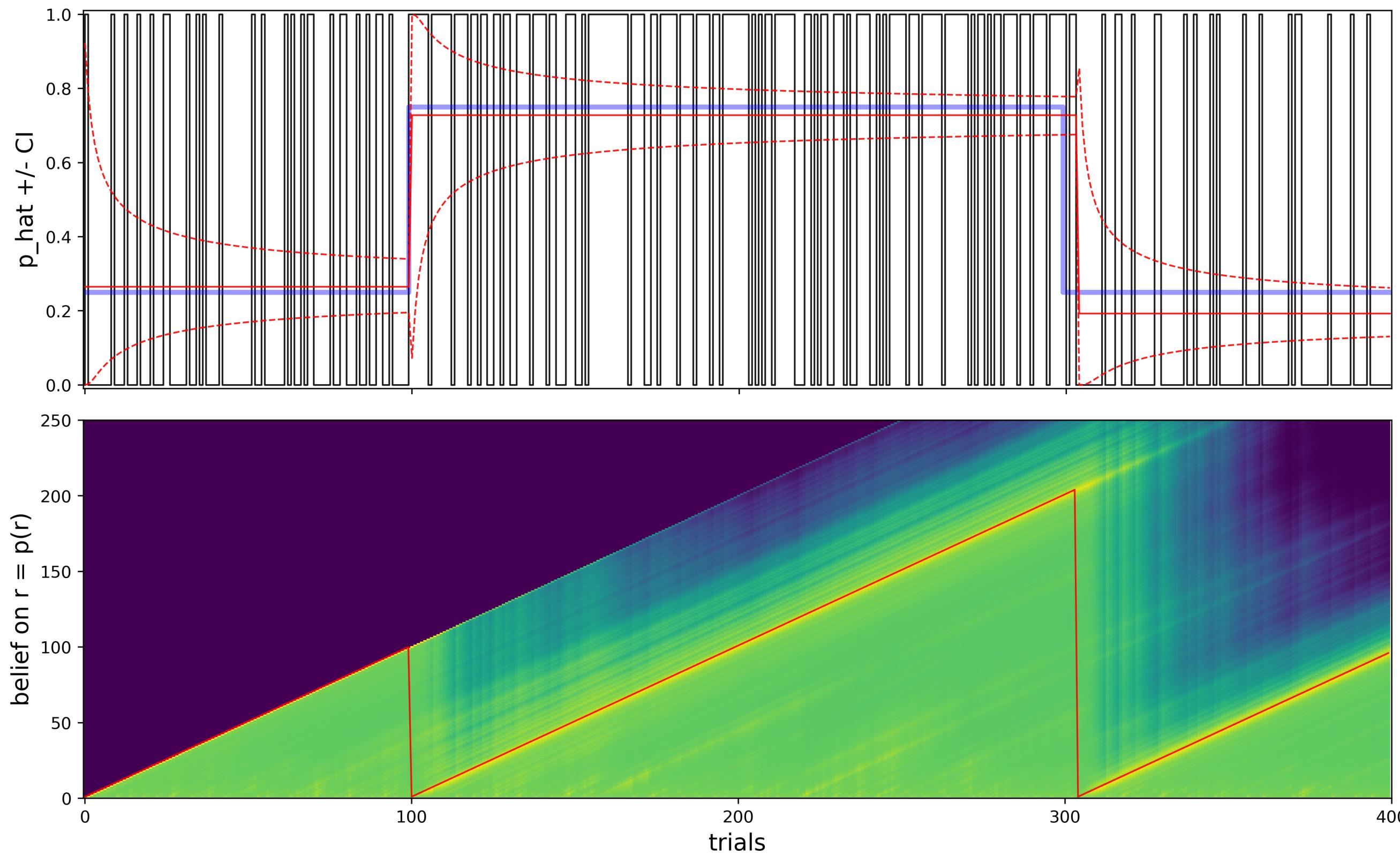
1. Should I stay or should I go?
2. Experimental protocol
3. The Bayesian Changepoint Detector
4. Results using the BCP
5. Application to RL?

# Application to RL? - Full model



full code @ [github.com/laurentperrinet/bayesianchangepoint](https://github.com/laurentperrinet/bayesianchangepoint)

# Application to RL? - With hindsight



full code @ [github.com/laurentperrinet/bayesianchangepoint](https://github.com/laurentperrinet/bayesianchangepoint)

# Should I stay or should I go? Adaption of human observers to the volatility of visual inputs

Laurent Perrinet



CausaL Kick-off, 5/4/2019

Acknowledgements:

- Rick Adams and Karl Friston @ UCL - Wellcome Trust Centre for Neuroimaging
- Jean-Bernard Damasse, Laurent Madelain and Anna Montagnini - ANR REM
- Frédéric Chavane - INT



This work was supported by ANR project ANR-18-AAPG-“CAUSAL, Cognitive Architectures of Causal Learning”.



<https://laurentperrinet.github.io/talk/2019-04-05-bbcp-causal-kickoff>