

DEPARTMENT OF EXPERIMENTAL PSYCHOLOGY

Anna Marzecová<sup>1</sup>, Eva Van den Bussche<sup>2</sup>, Tom Verguts<sup>1</sup>

<sup>1</sup>Ghent University, Belgium

<sup>2</sup>KU Leuven, Belgium

# ATTENTIONAL ORIENTING RELIES ON BAYESIAN ESTIMATES OF EXPECTED AND UNEXPECTED UNCERTAINTY

## INTRODUCTION

### Attentional orienting relies on Bayesian estimates of uncertainty

Yu and Dayan's (2005) theoretical computational model proposes that the attentional system relies on two forms of uncertainty estimates:

- *Expected uncertainty* (EUn) relates to unreliability of predictive relationships within a familiar context, and is assumed to be signaled by acetylcholine (ACh).
- *Unexpected uncertainty* (UUn) is triggered by sudden changes of the environmental context, and is assumed to be signaled by noradrenaline (NE).
- How do expected and unexpected uncertainty influence attentional orienting?

### Link between uncertainty estimates and neuromodulatory brainstem responses

- Pupil size – a proxy for neuromodulatory brainstem responses
- Fluctuations in pupil size likely reflect expected and unexpected uncertainty estimates

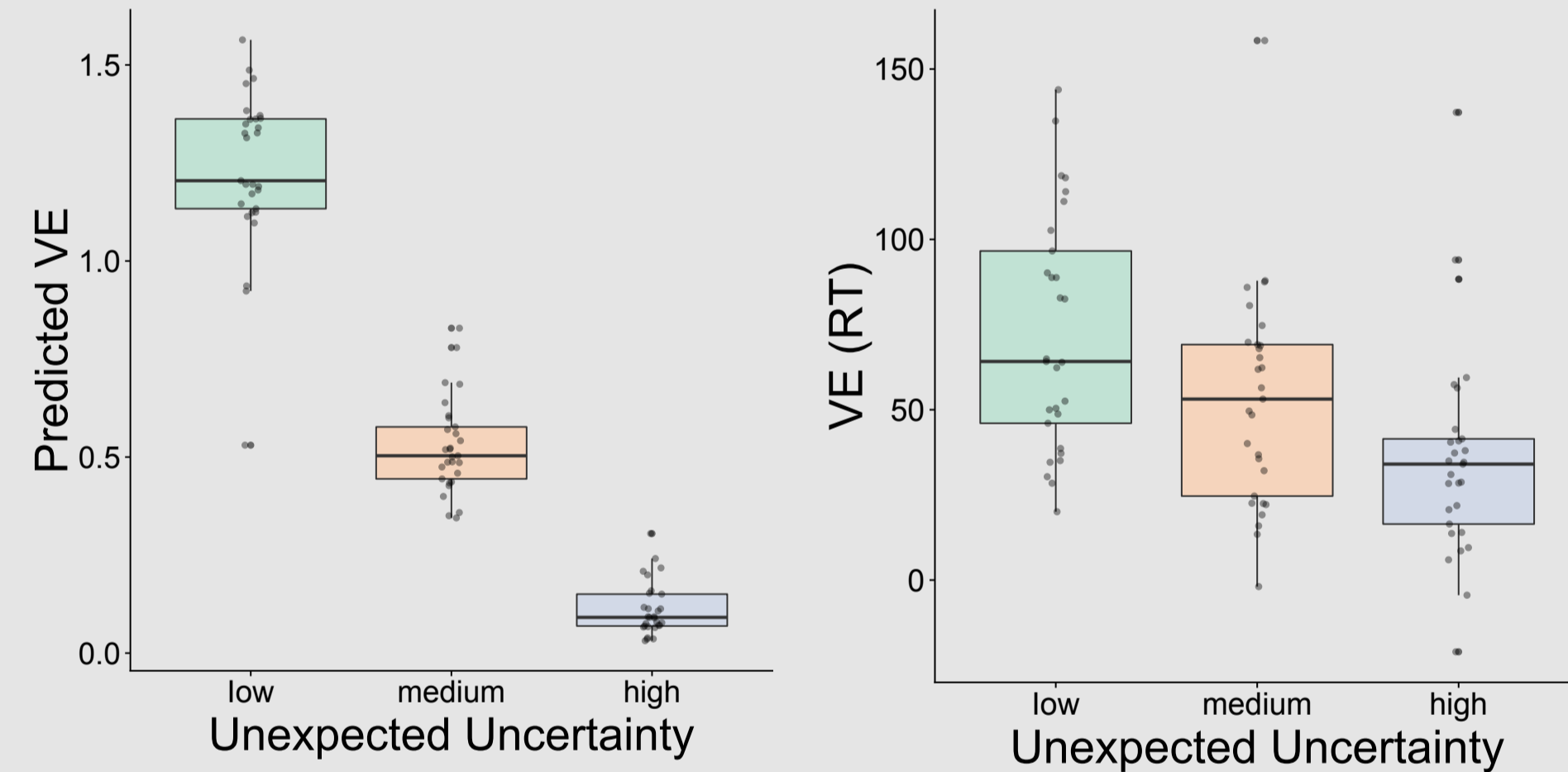
## METHODS

### Experimental task

- Participants (N=29) performed a spatial cueing task, which manipulated EUn and UUn.
- 640 trials in 16 blocks
- Eye-tracking: SMI RED250 eye-tracker; sampling rate: at 250 Hz
- Participants reported on their inferences about the relevant cue after each 40 trials (mean accuracy: 81% [56–100%]; convergence with the model: 82% [50–100%]).
- Optimization: Nelder-Mead simplex method to increase correlation coefficient between trial-by-trial PE values and response time (RT) values

## RESULTS

### Behavioural effects



### Single trial RT analysis

LME: RT as a function validity, trial-wise model-derived EUn and UUn; and participant (random effect)

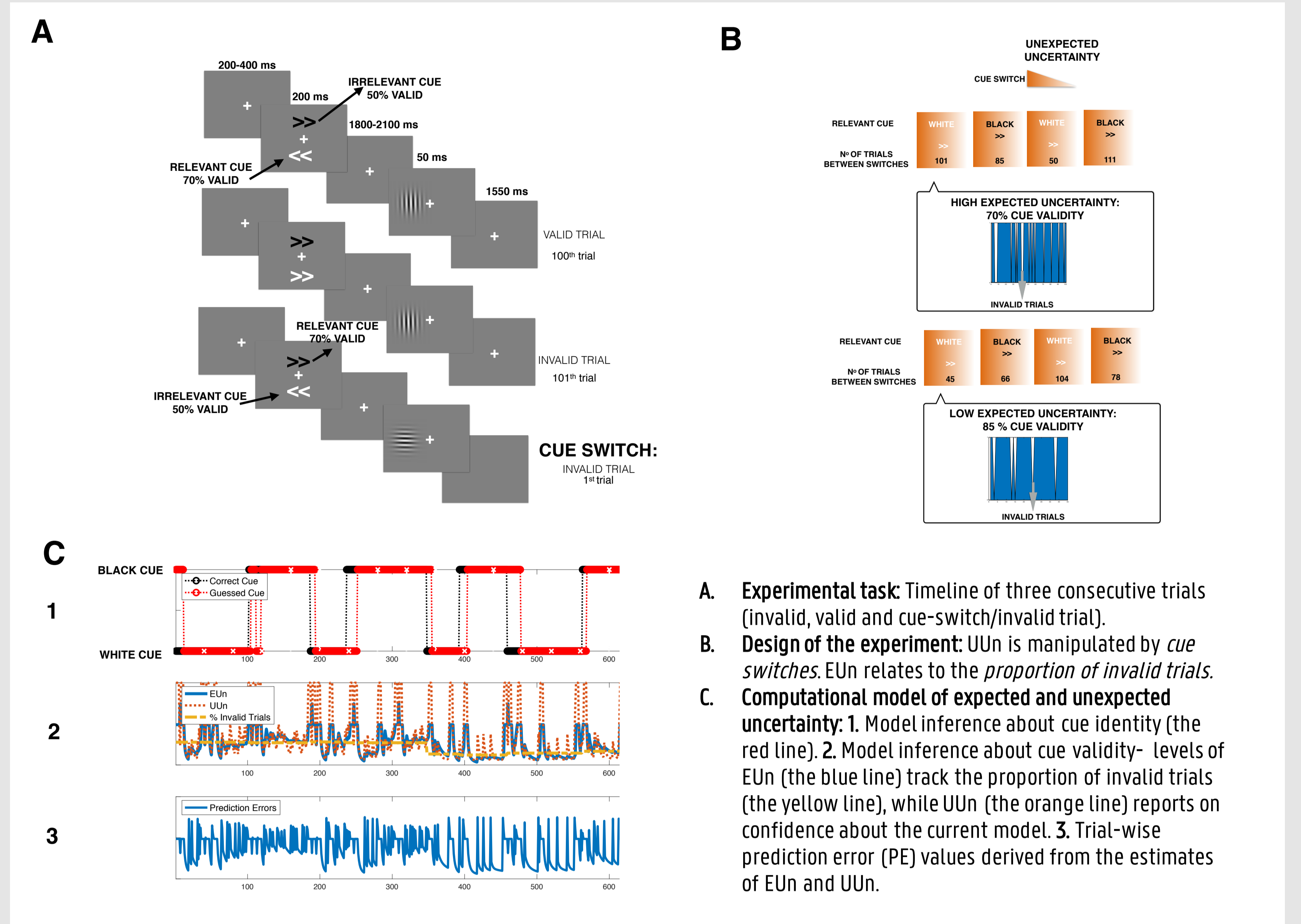
Model	$\chi^2$	BIC	-BF <sub>10</sub>
validity	-66.05	171722	$1.10 \times 10^{288}$
UUn*validity	82.75	171581.3	$4.04 \times 10^{30}$

- RT varies as a function of UUn and validity
- Validity effect (VE): RT are slower on invalid vs. valid trials
- VE decreases with increasing UUn levels

## DISCUSSION & CONCLUSIONS

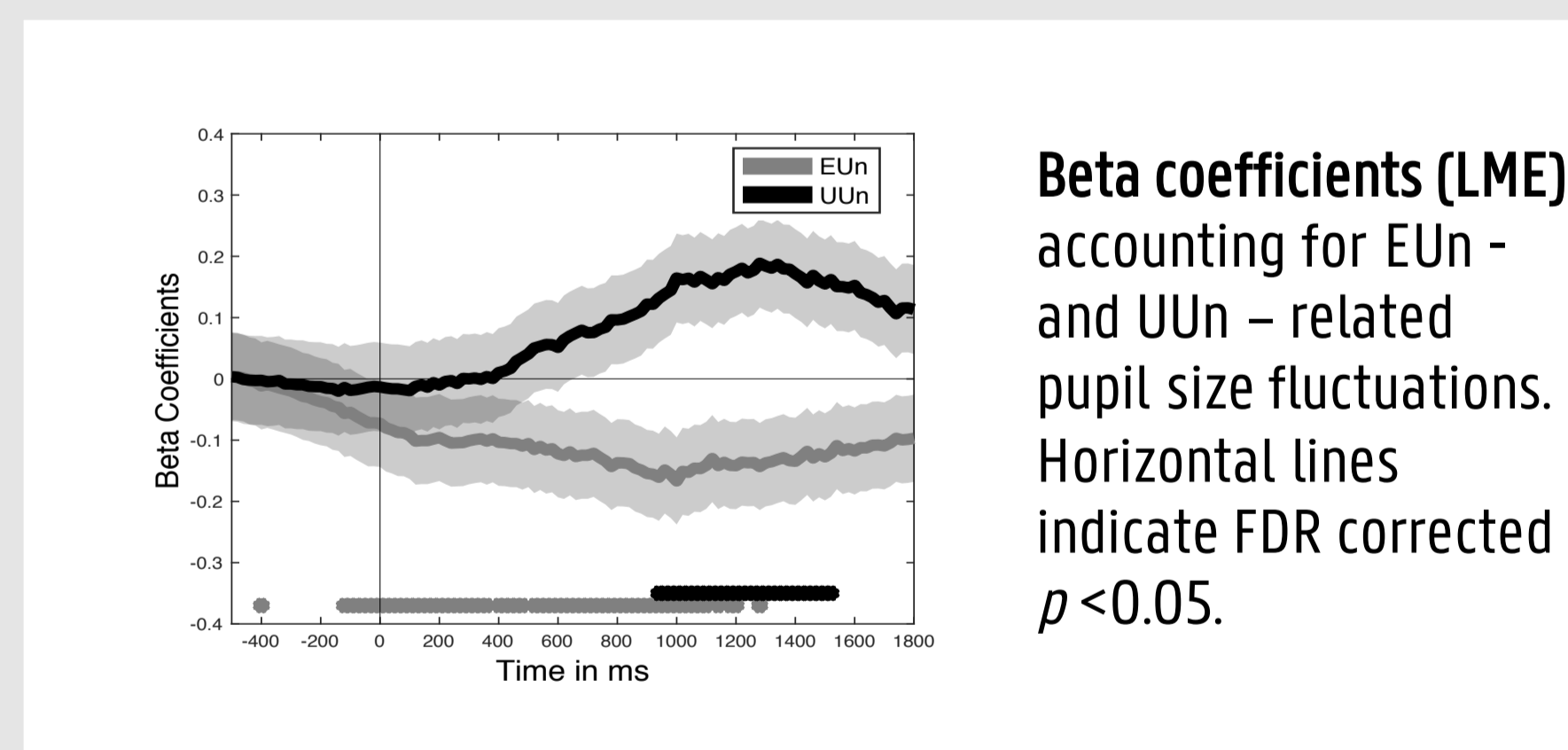
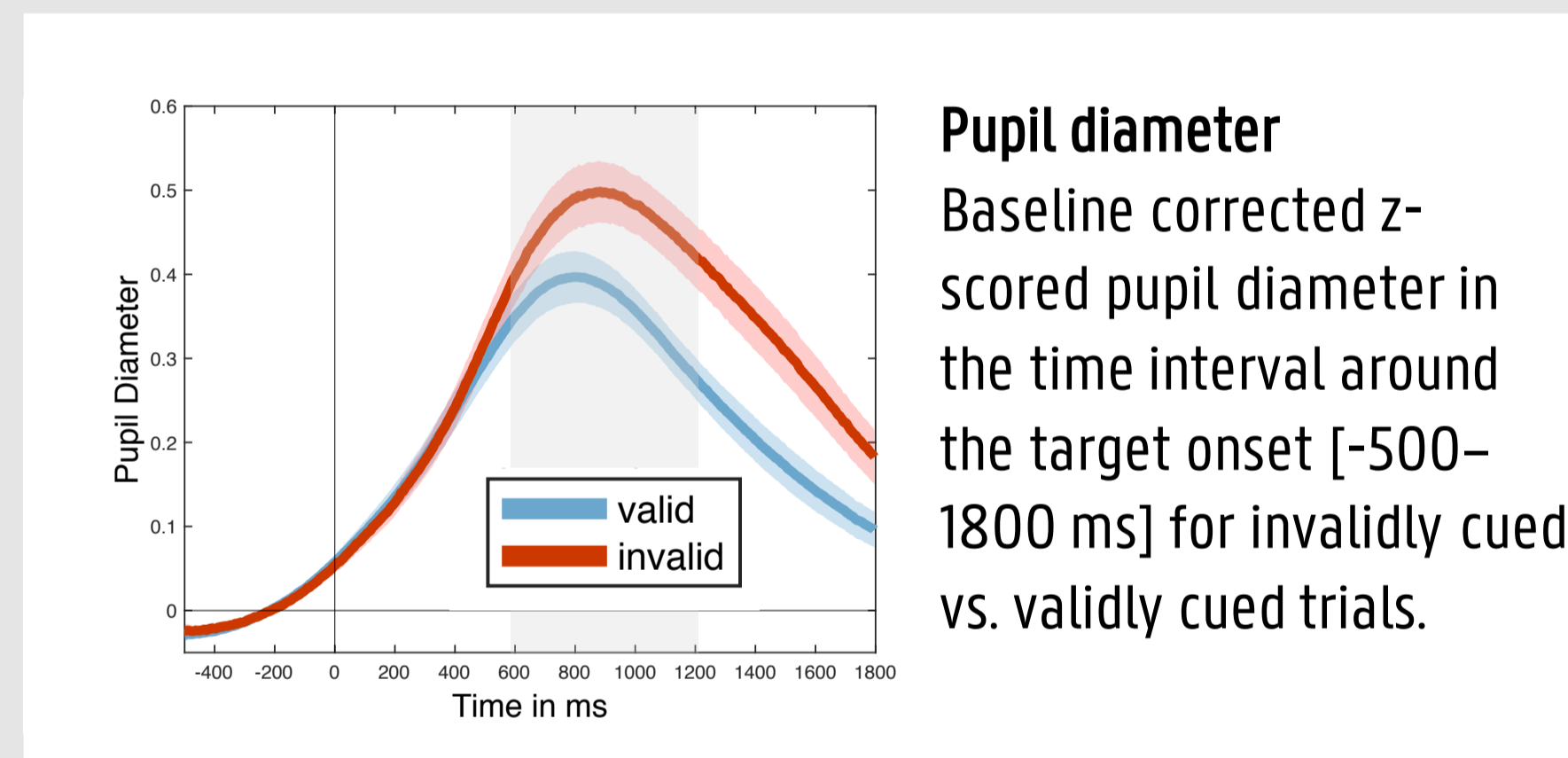
### Attentional orienting relies on uncertainty estimates

- Attentional orienting is less efficient under high unexpected uncertainty.
- The influence of unexpected uncertainty in behavior seems more reliable than the effect of expected uncertainty. Nevertheless, increasing levels of both expected uncertainty and unexpected uncertainty slowed down responses on validly cued trials.
- Pupil diameter – a proxy for neuromodulatory brainstem responses - reflects both expected and unexpected uncertainty estimates.
- Effects of EUn and UUn on pupil size data are dissociable
- EUn effects detected earlier in the time course, and are more sustained; UUn effects are detected later in the time course, and are more phasic.
- Pupil diameter decreases with increasing expected uncertainty (on invalid trials). This result is consistent with previous evidence showing that pupil diameter scales with surprise (Preuschoff, 2011).
- Pupil diameter increases with unexpected uncertainty (mostly on valid trials): phasic NE tracks unexpected uncertainty.



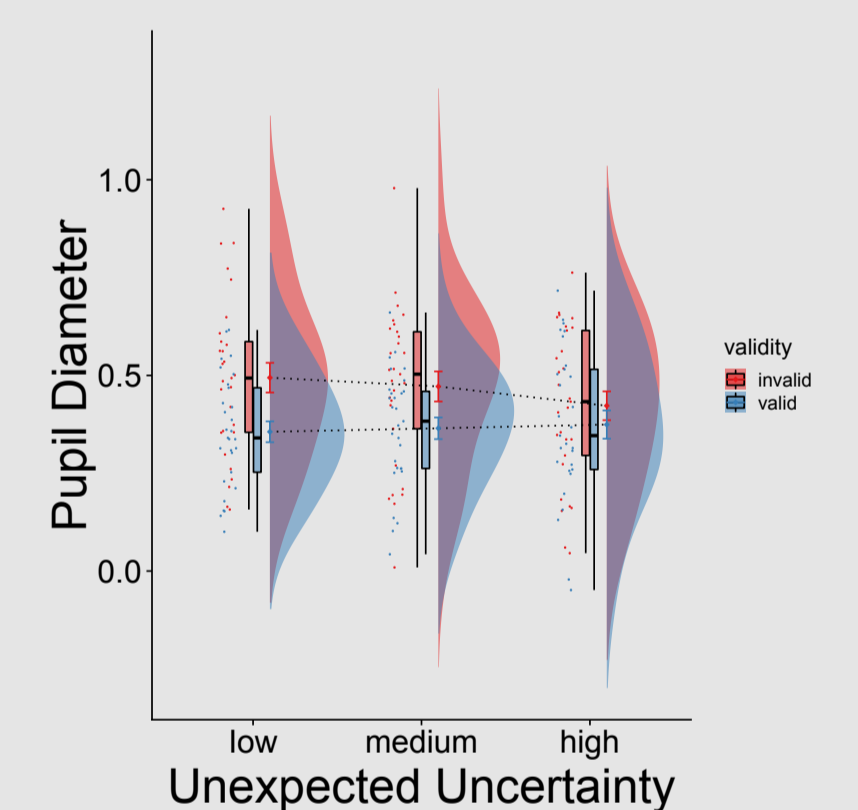
1. Model inference about cue validity (the red line).
2. Model inference about cue validity- levels of EUn (the blue line) track the proportion of invalid trials (the yellow line), while UUn (the orange line) reports on confidence about the current model.
3. Trial-wise prediction error (PE) values derived from the estimates of EUn and UUn.

### Pupil diameter

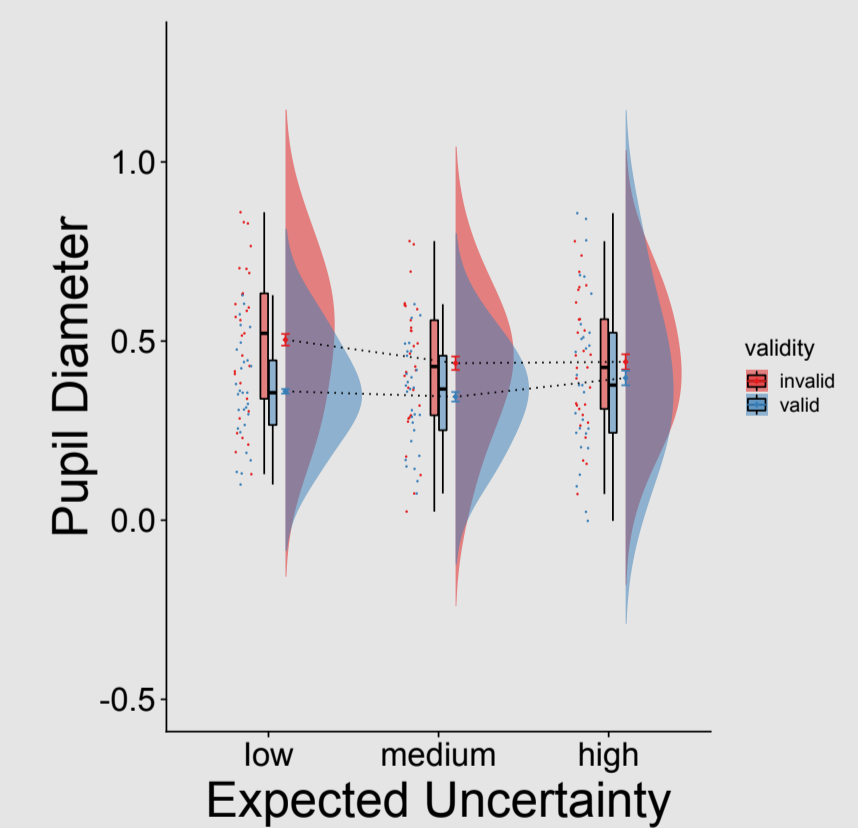


- Pupil diameter fluctuates as a function of validity : it increases on invalidly cued trials
- Pupil diameter increases with increasing Uun (on valid trials)
- Pupil diameter varies as a function EUn: it is the largest under low EUn on invalid trials

### Unexpected uncertainty



### Expected uncertainty



### Contact

Anna.Marzecova@ugent.be

www.marzecova.com

@marzecova