

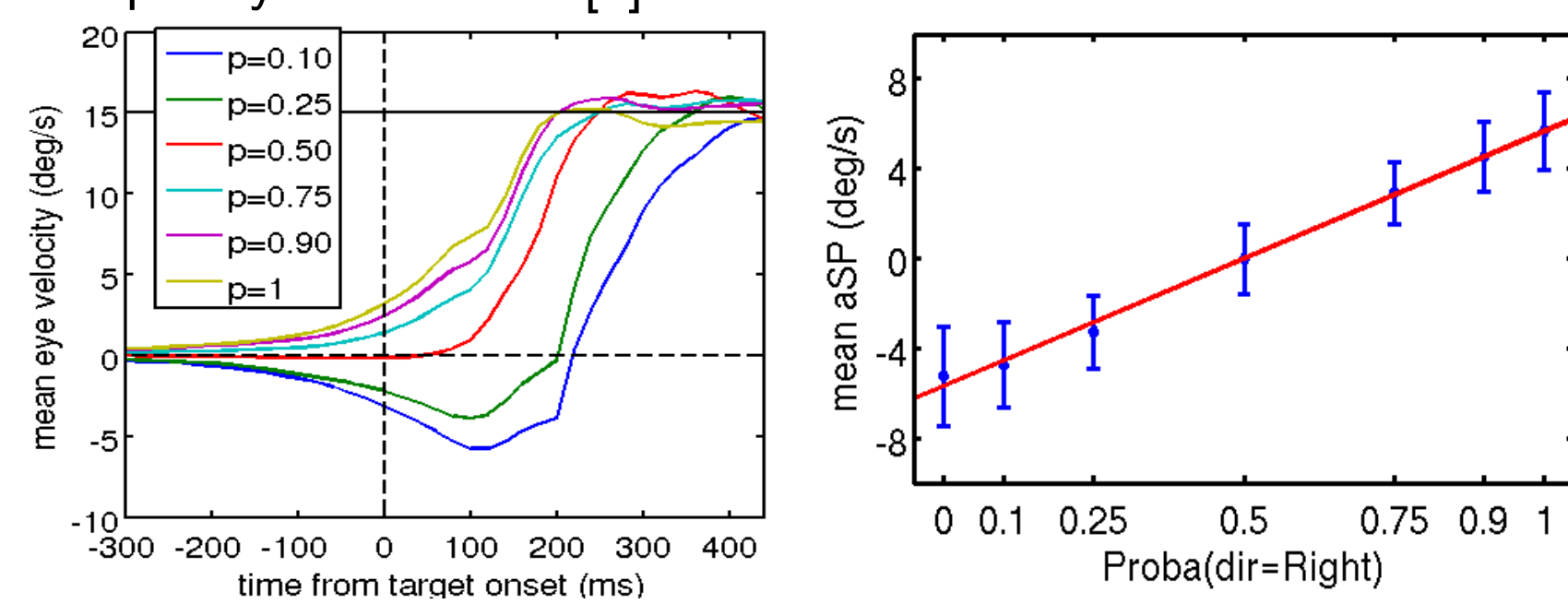
Estimating and anticipating a dynamic probabilistic bias in visual motion direction

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Problematic

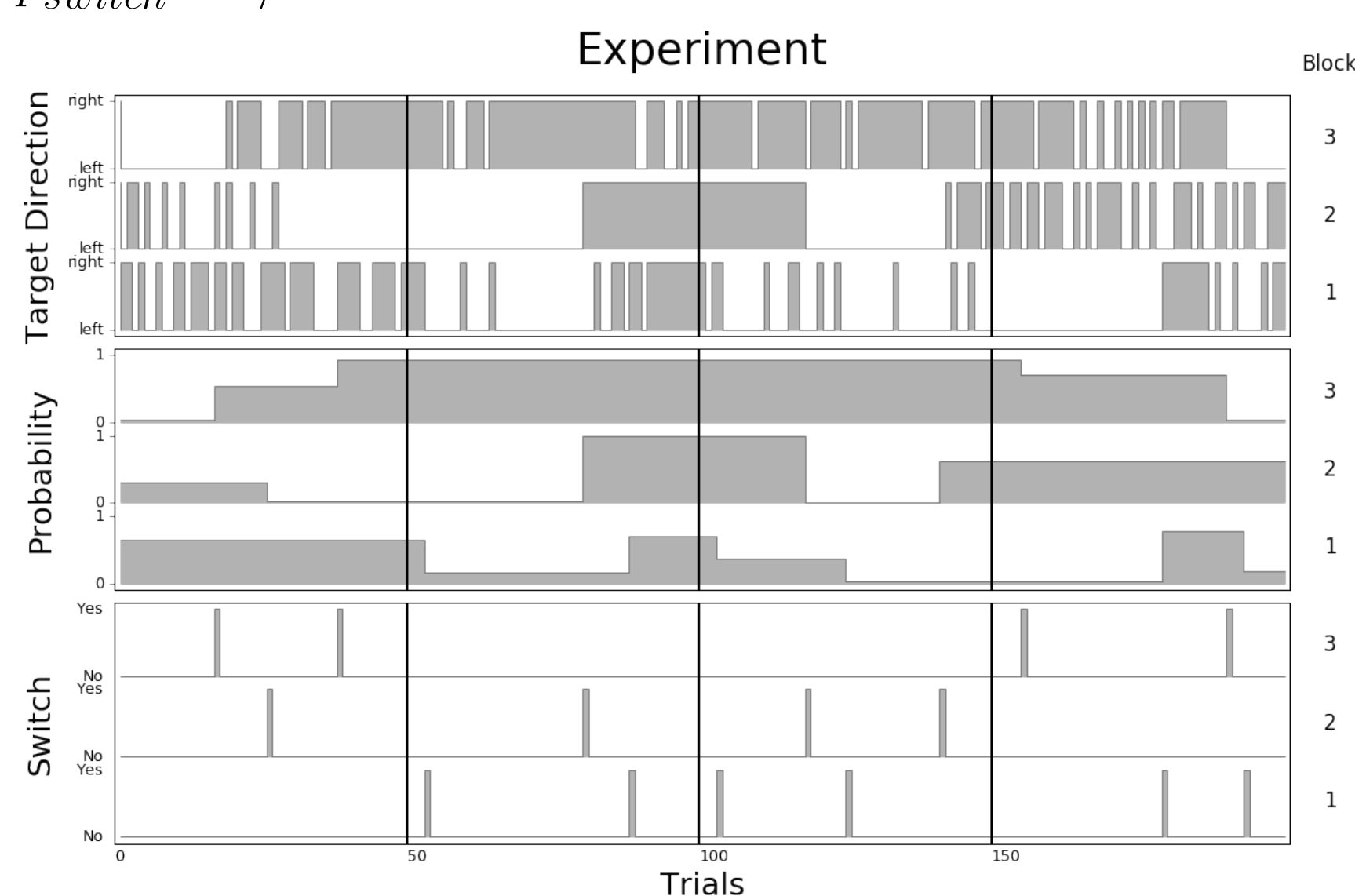
Humans are able to accurately track a moving object with a combination of saccades and smooth eye movements. These movements allow us to align and stabilize the object on the fovea, thus enabling high-resolution visual detection. When predictive information is available about target motion, anticipatory smooth pursuit eye movements (aSPEM) are efficiently generated before target appearance, which reduce the typical sensorimotor delay between target motion onset and foveation. It is generally assumed that the role of anticipatory eye movements is to limit the behavioral impairment due to eye-to-target position and velocity mismatch. By manipulating the probability for target motion direction we were able to bias the direction and mean velocity of aSPEM, as measured during a fixed duration gap before target ramp-motion onset. This suggests that probabilistic information may be used to inform the internal representation of motion prediction for the initiation of anticipatory movements [1].



However, such estimate may become particularly challenging in a dynamic context, where the probabilistic contingencies vary in time in an unpredictable way. In addition, whether and how the information processing underlying the buildup of aSPEM is linked to an explicit estimate of probabilities is unknown.

Material and Method

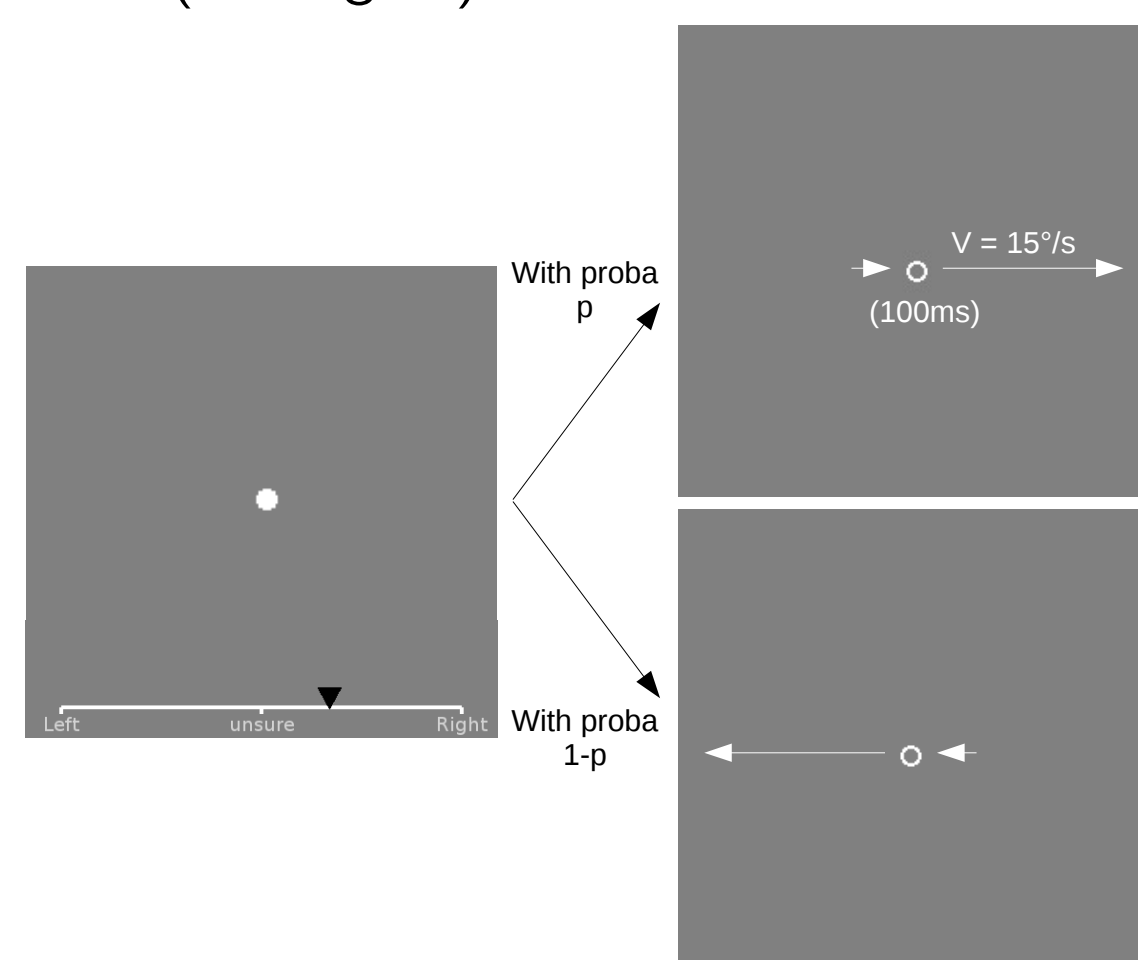
In order to answer these questions, we have set up an experiment comprising 3 blocks of 200 trials. For each trial, a target makes either to the left or to the right, this direction being drawn from a Bernoulli process. The probability of this process varied in a piecewise-constant (that is, a step function varying between 0 and 1), similarly to Meyniel et al. [2]. The occurrence of these switches is itself drawn from a Bernoulli process of probability $p_{switch} = 1/40$.



We asked subjects to perform two tasks on different days :

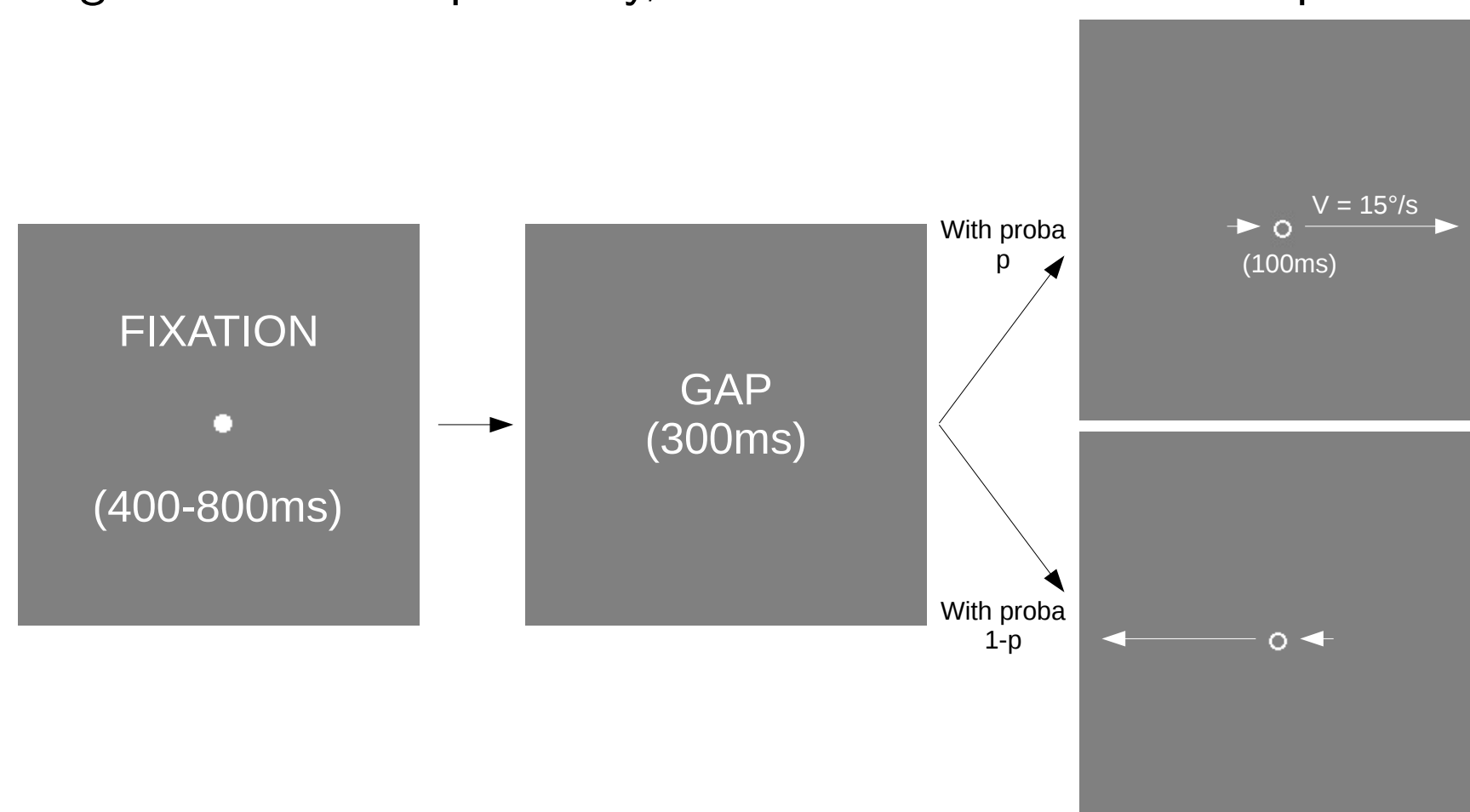
The Bet

In this first part, the subjects must simply answer before each trial at the question "How sure are you that the target will go left or right". This was performed by adjusting a cursor on the screen using the mouse (see Figure).

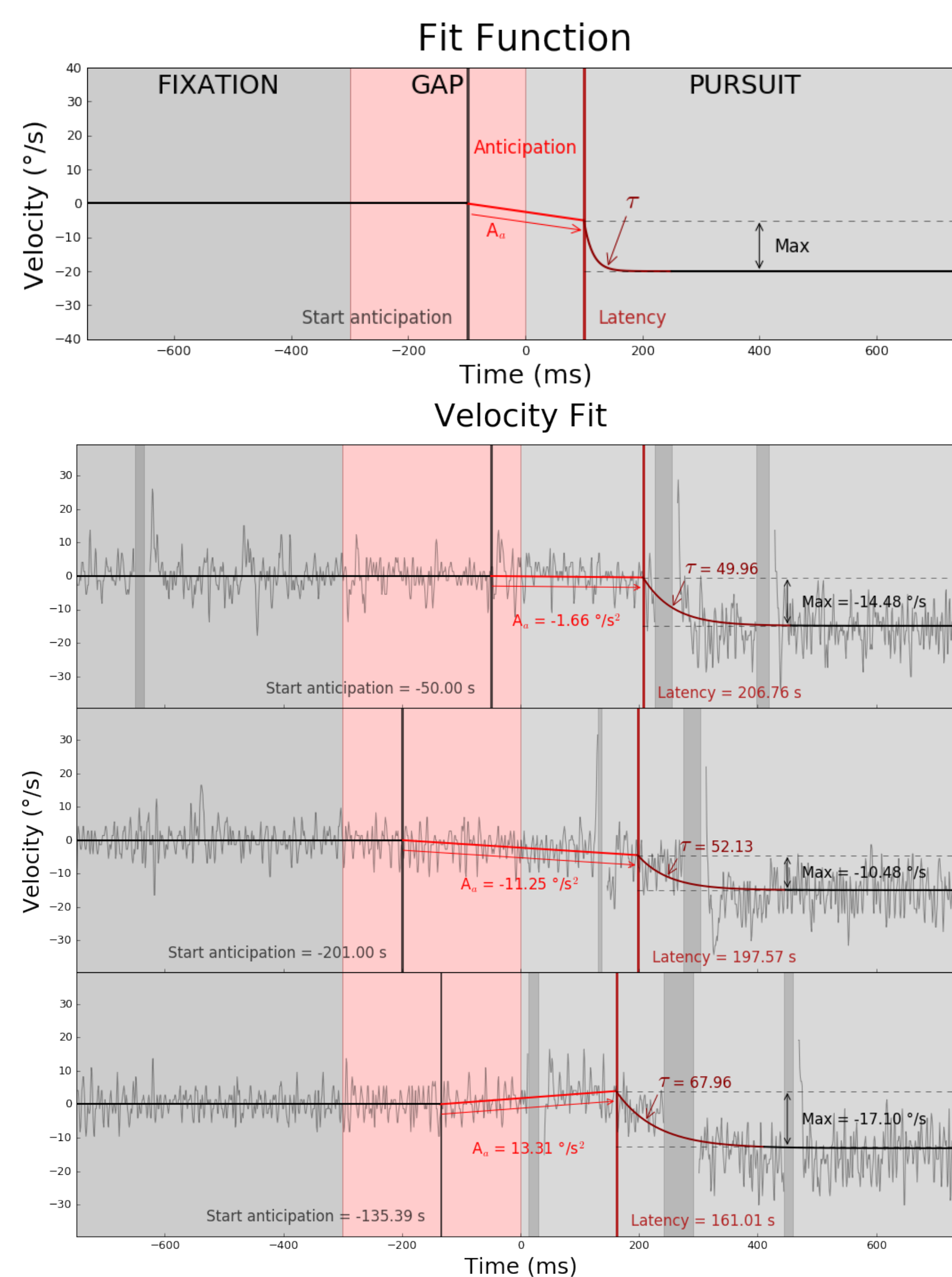


Eye movements recording

Then, we recorded their eye movements as they were tracking the target's motion. Importantly, we used that exact same sequence.



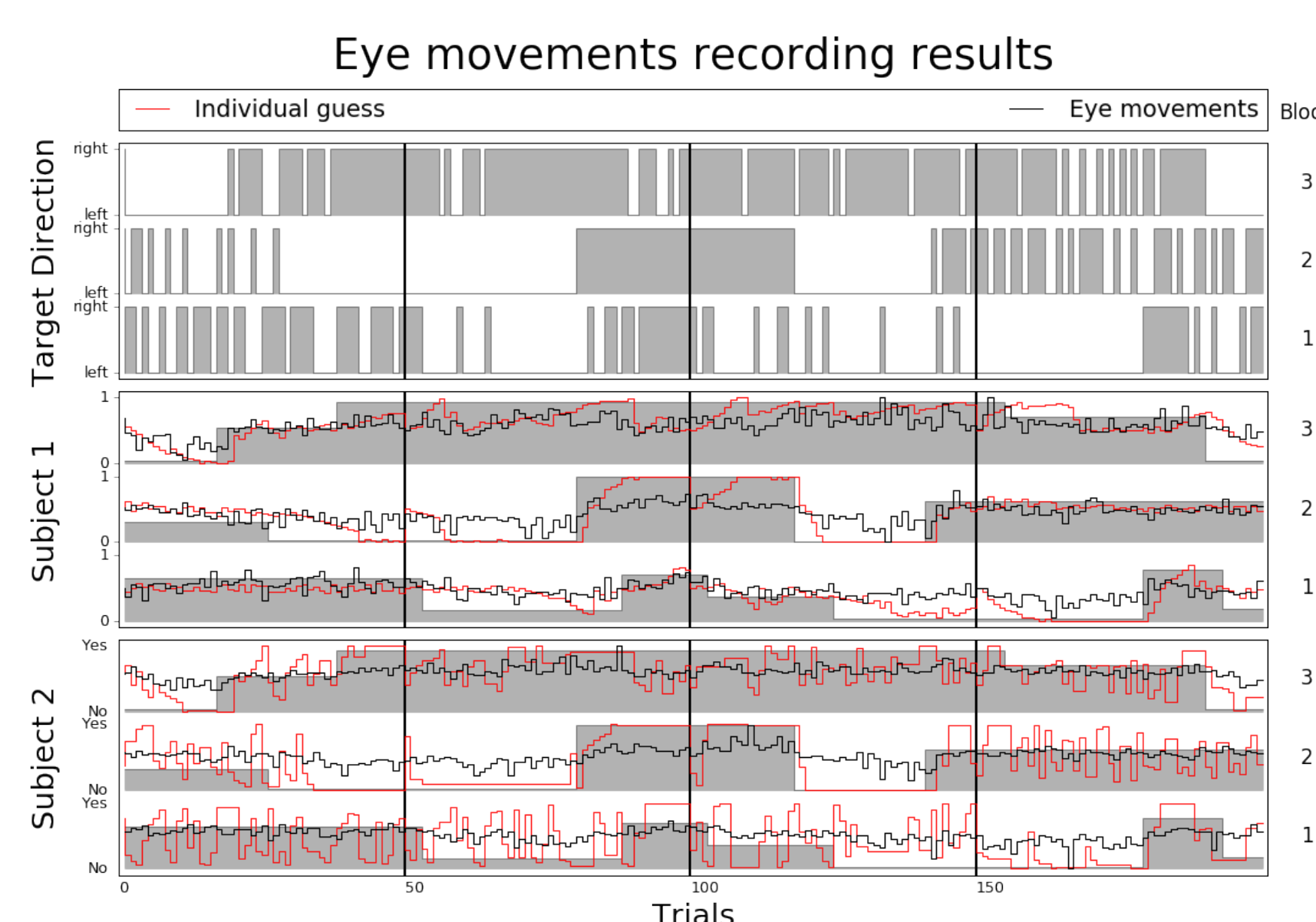
In order to extract the relevant parameters of the oculomotor responses, we developed new tools based on a best-fitting procedure of predefined patterns and in particular the typical smooth pursuit velocity profile that was recorded for the aSPEM (Top row). This was applied to each trial individually, and we show below some prototypical example of respectively a neutral, anticipatory positive and anticipatory negative aSPEMs examples (respectively second to bottom rows) :



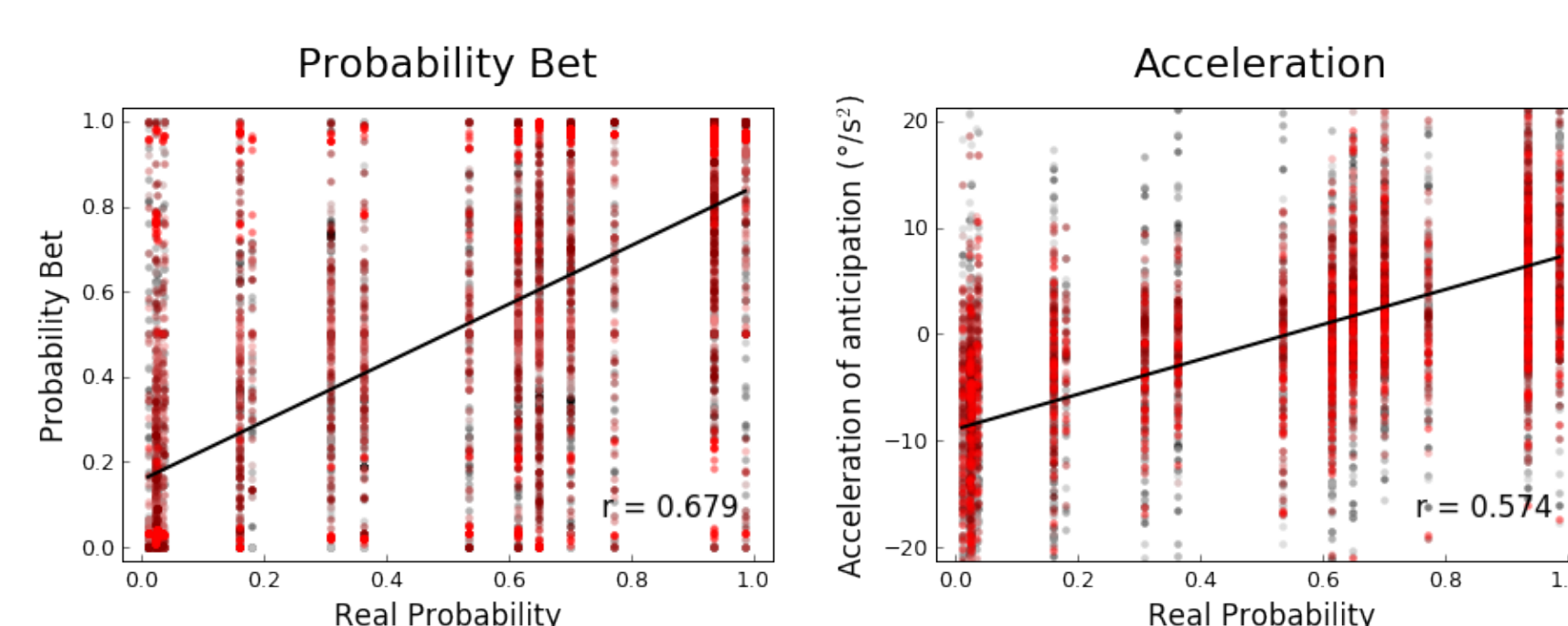
Results

Eye movements recording and the Bet

Example of results obtained during the bet and the recording :



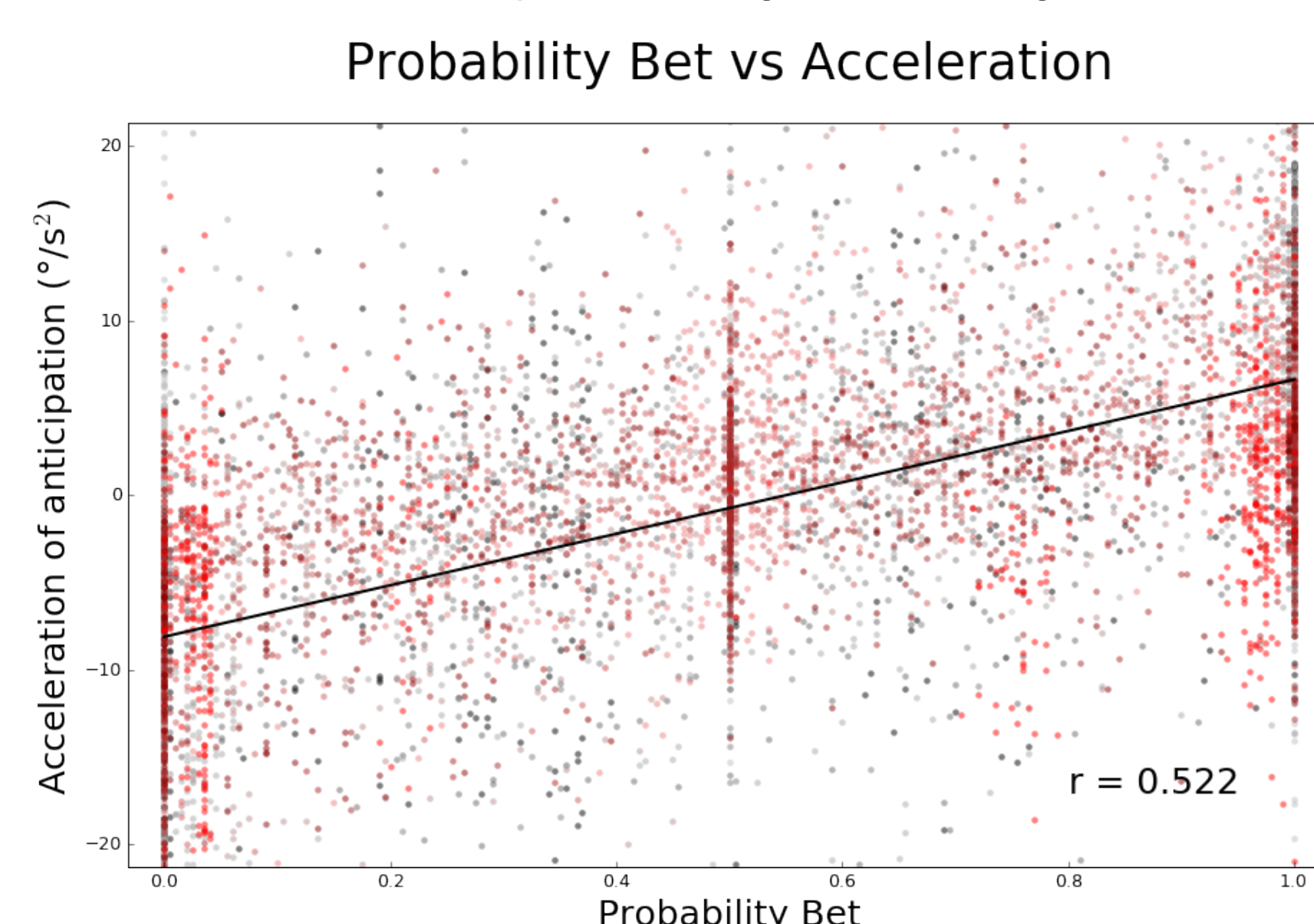
Let's plot the value of the bet (probability bet) and the acceleration of anticipation (slope of aSPEM) as a function of the real probability at every given trial :



Which give a strong and positive Pearson coefficient.

Relating the Bet to the Recording

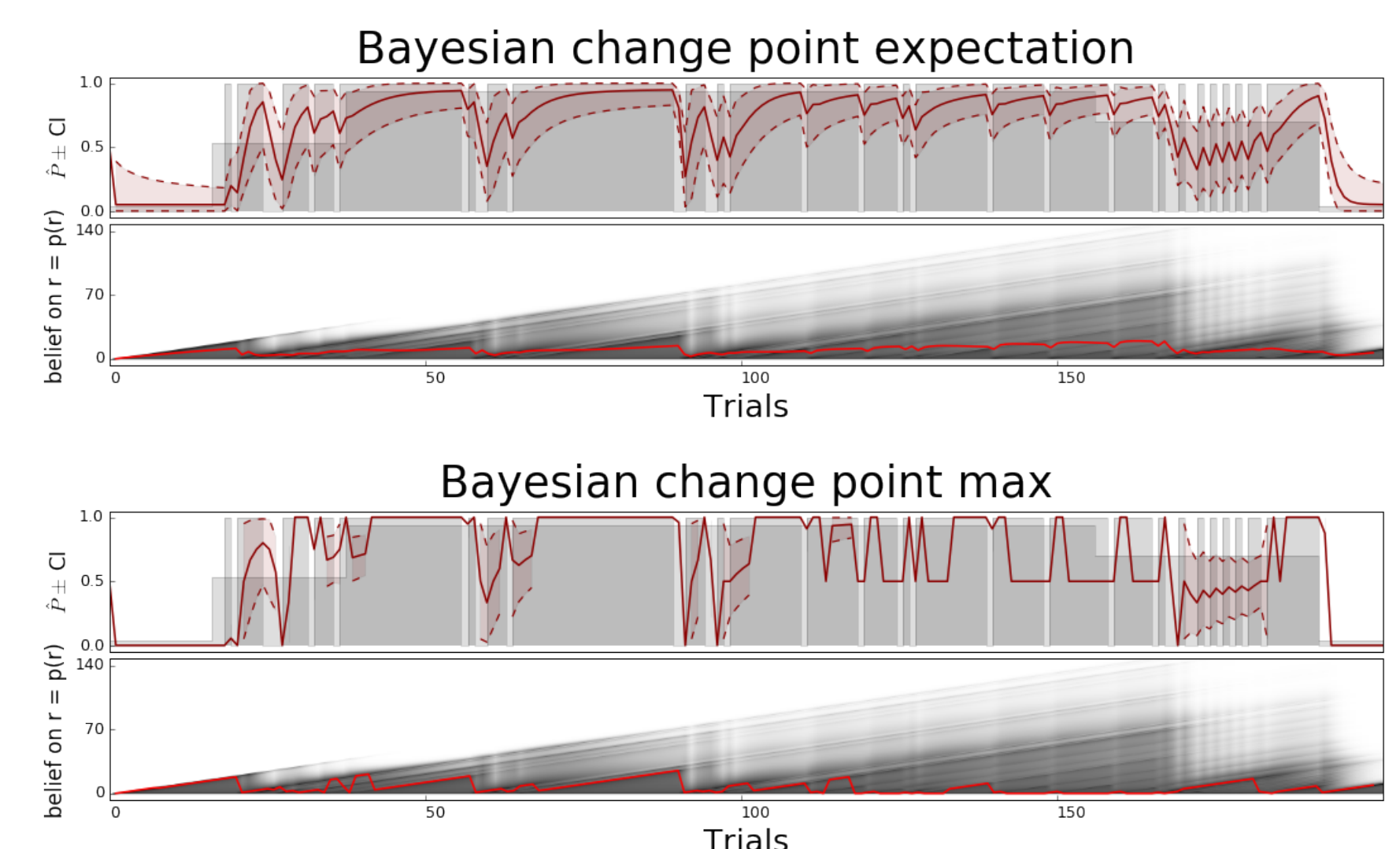
We now compare the value of bet during the bet experiment with the acceleration of anticipation during the recording :



Model

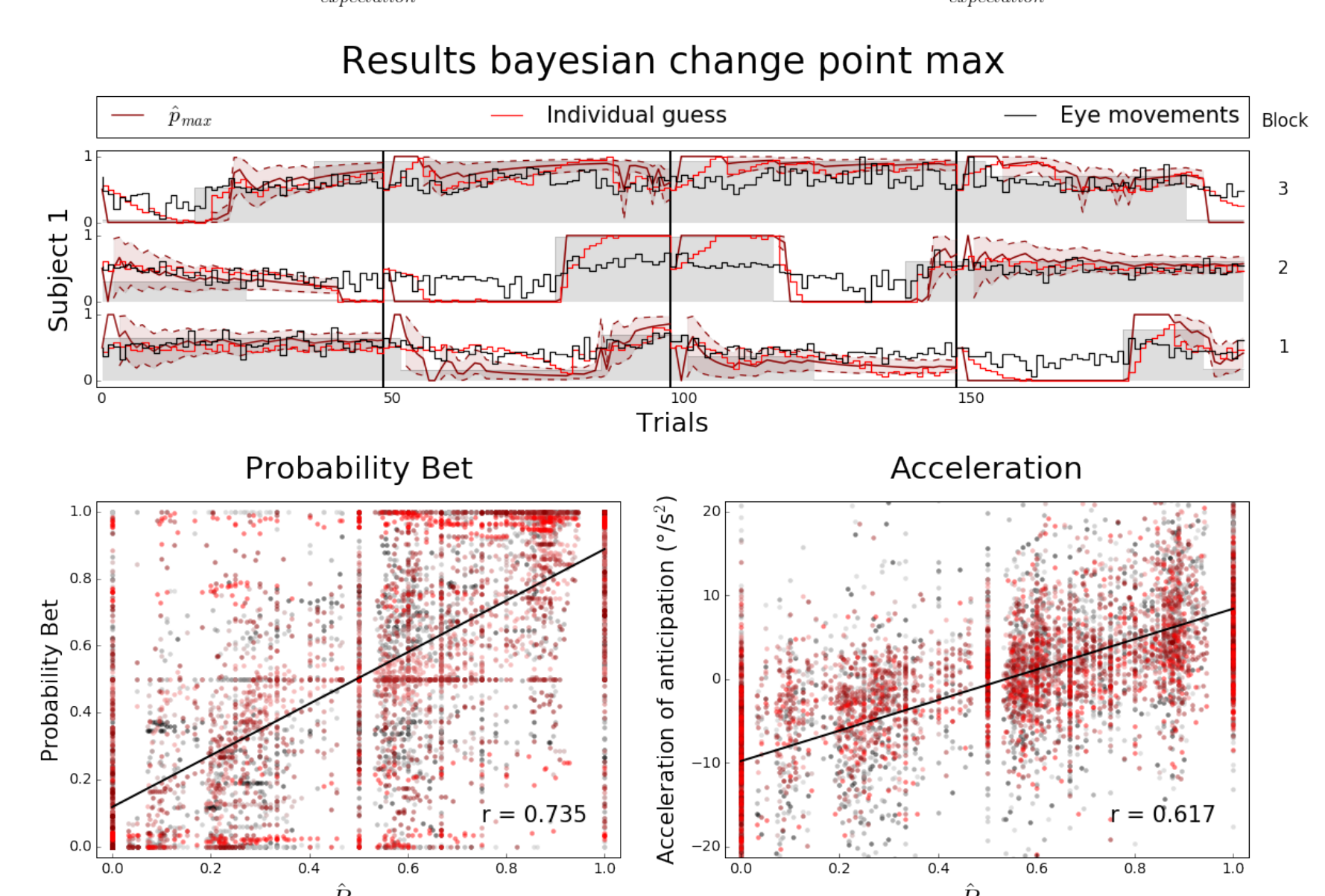
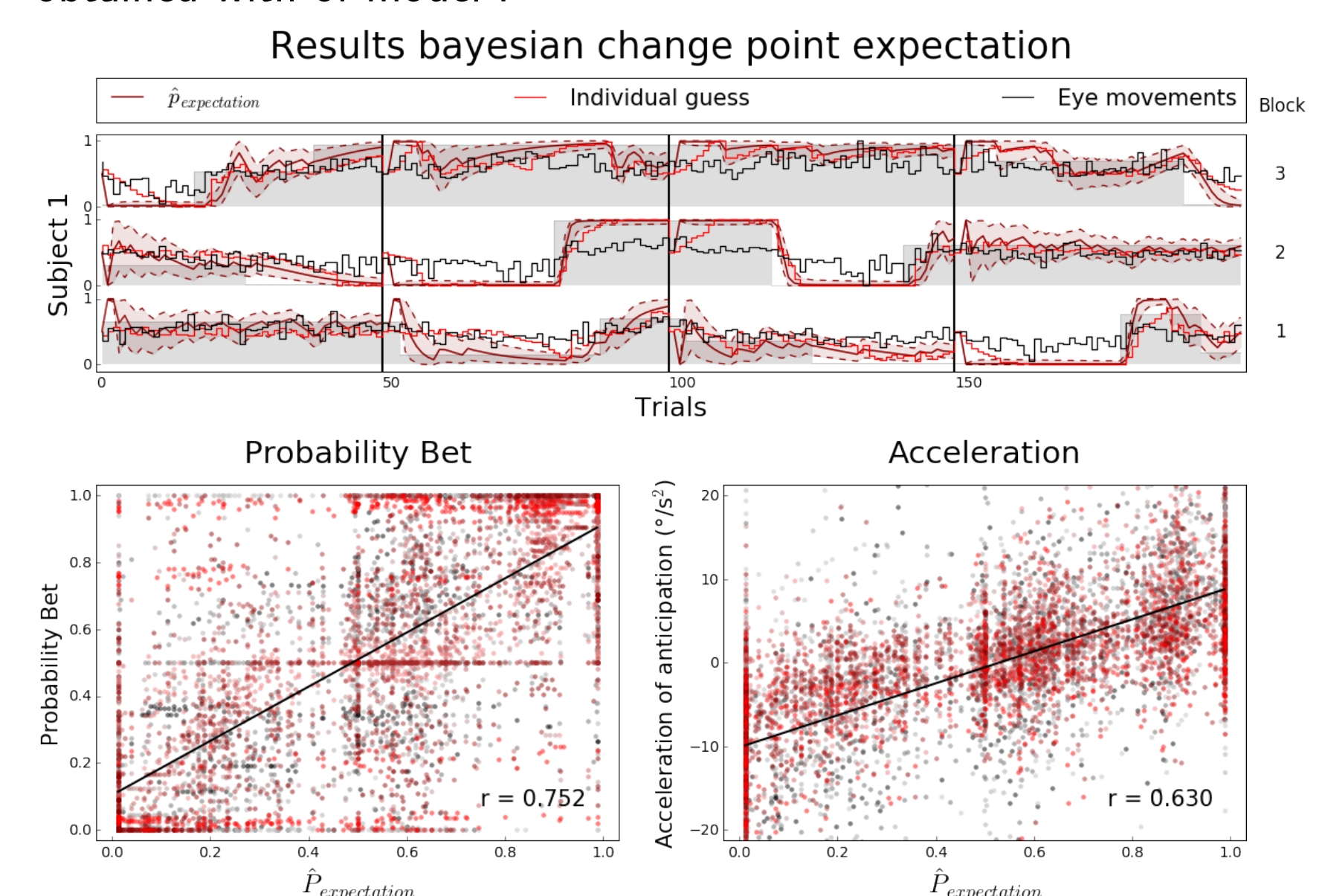
Bayesian change point

We have adapted Adams and Mackay's Bayesian Online Change-point Detection model [3] to model an agent behaving like the subject. For the third blocks we have these results:



Relating Bayesian change point and results

We now compare the value of bet during the bet experiment and the acceleration of anticipation during the recording with the value obtained with of model :



Conclusions

- There is a strong correlation between the real probability and the value of the bet,
- there is a strong correlation between the strength of anticipation and the probability of the process,
- we are now developing a Bayesian model of an agent computing an estimate of changing points. This allows to dynamically infer the probability of the process and should provide with a more significant correlation. The parameters of such agents will be crucial to characterise the differences in the response of the subjects.

References

- [1] A. Montagnini et al. "Anticipatory eye-movements under uncertainty: a window onto the internal representation of a visuomotor prior". In: *Journal of Vision* 10.7 (2010), p. 554.
- [2] F. Meyniel et al. "Neurocomputational account of how the human brain decides when to have a break." In: *Proceedings of the National Academy of Sciences of the United States of America* 110.7 (2013), pp. 2641–2646. DOI: 10.1073/pnas.1211925110.
- [3] R. Prescott Adams and D. J. C. MacKay. "Bayesian Online Changepoint Detection". In: *ArXiv e-prints* (Oct. 2007).