Estimating and anticipating a dynamic probabilistic bias in visual motion direction

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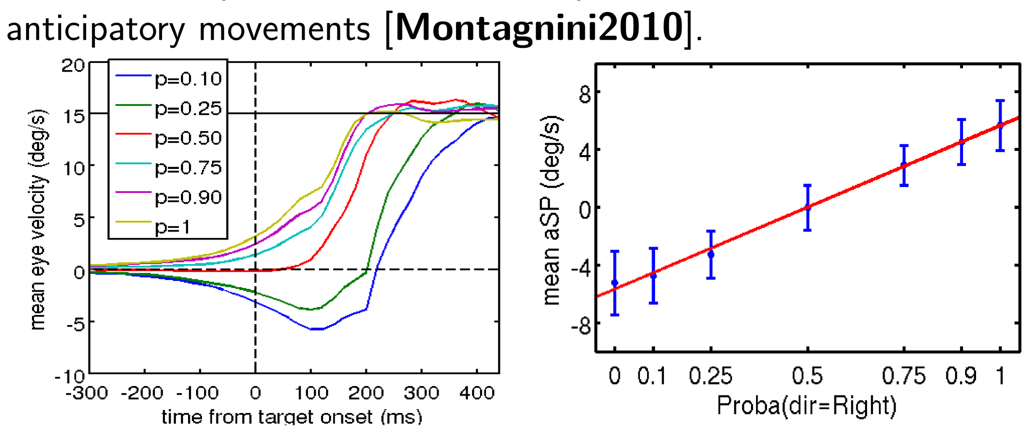
Problematic

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.

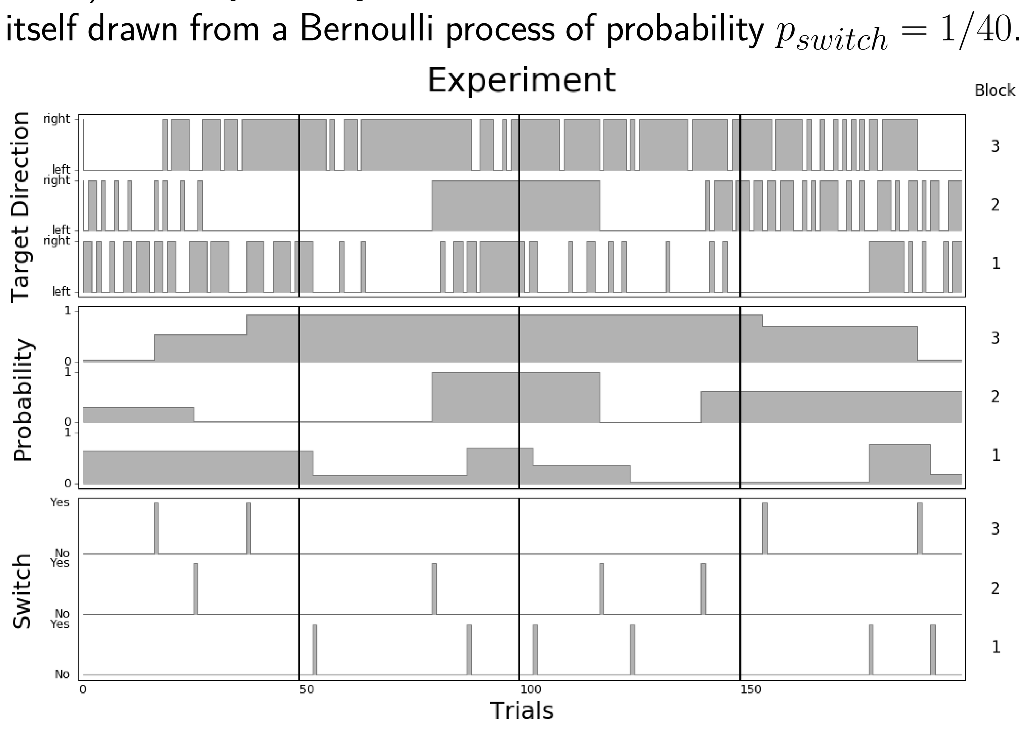
By manipulating the probability for target motion direction we were able to bias the direction and mean velocity of aSPEM, as measured during a fixed duration gap before target ramp-motion onset. This suggests that probabilistic information may be used to inform the internal representation of motion prediction for the initiation of anticipatory movements [**Montagnini2010**].



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

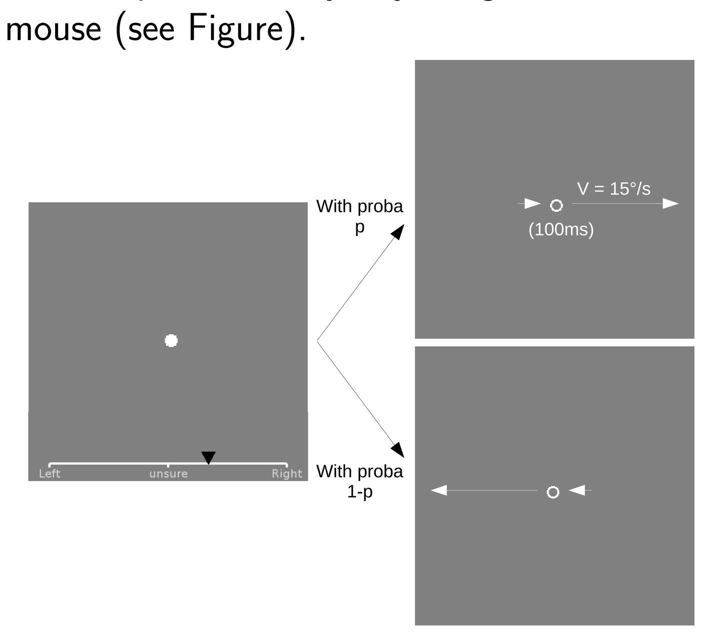
In order to answer these questions, we have set up an experiment comprising 3 blocks of 200 trials. For each trial, a target makes either to the left or to the right, this direction being drawn from a Bernoulli process. The probability of this process varied in a piecewise-constant (that is, a step function varying between 0 and 1), similarly to **Meyniel13**. The occurence 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 :

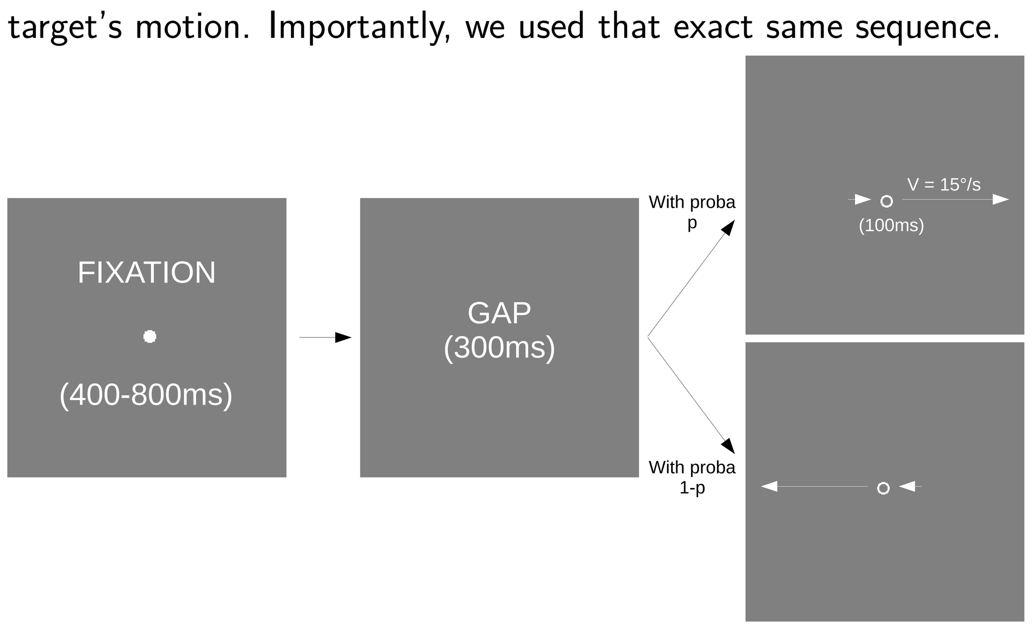
The Bet

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).

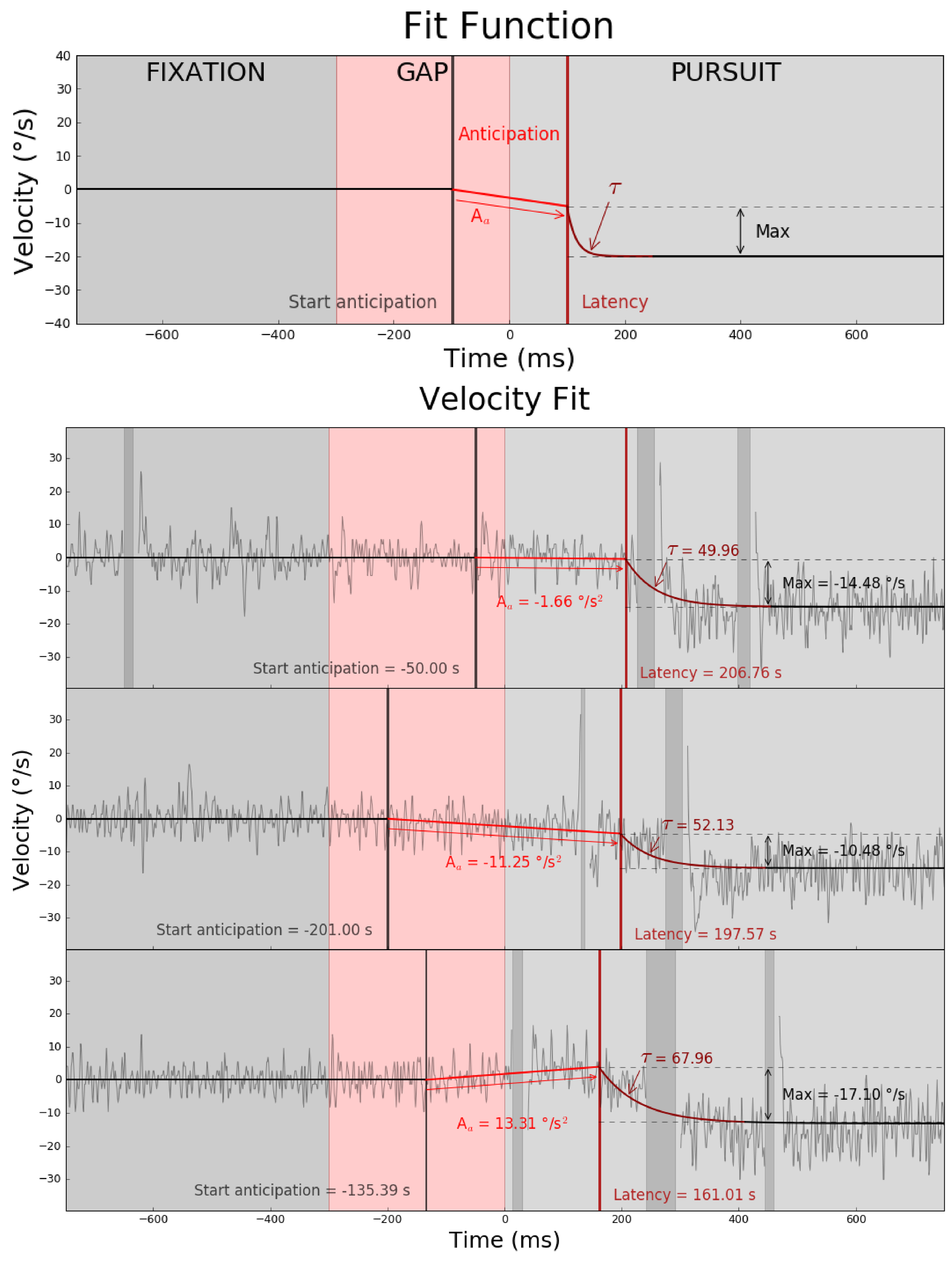


Eye mouvements recording

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



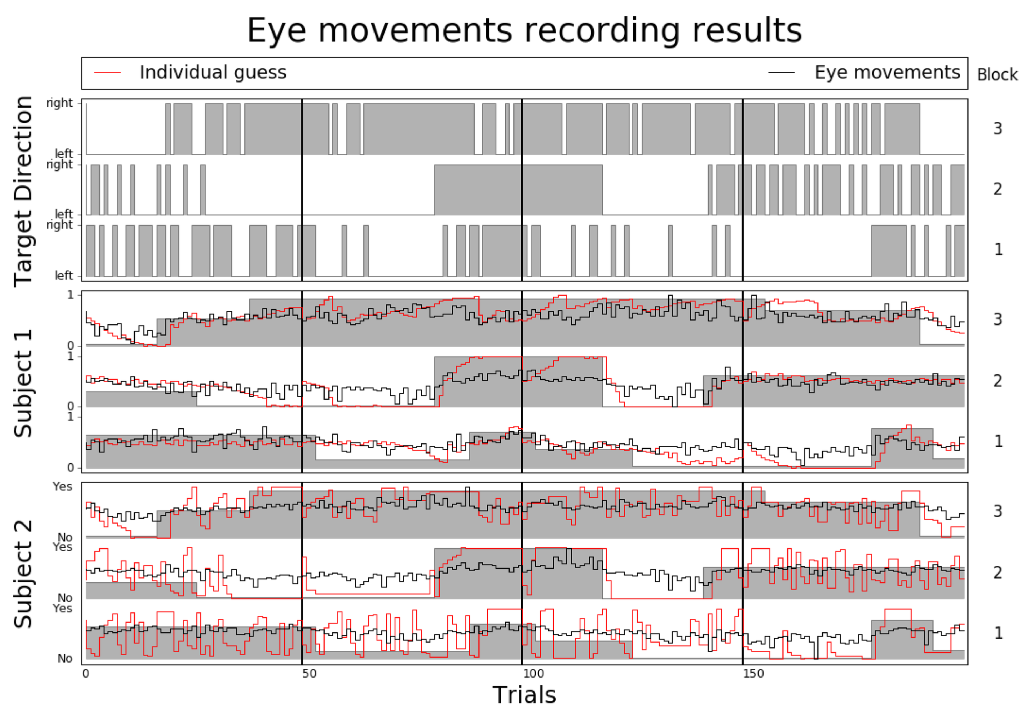
In order to extract the relevant parameters of the oculomotor responses, we developed new tools based on a best-fitting procedure of predefined patterns and in particular the typical smooth pursuit velocity profile that was recorded for the aSPEM (Top row). This was applied to each trial individually,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



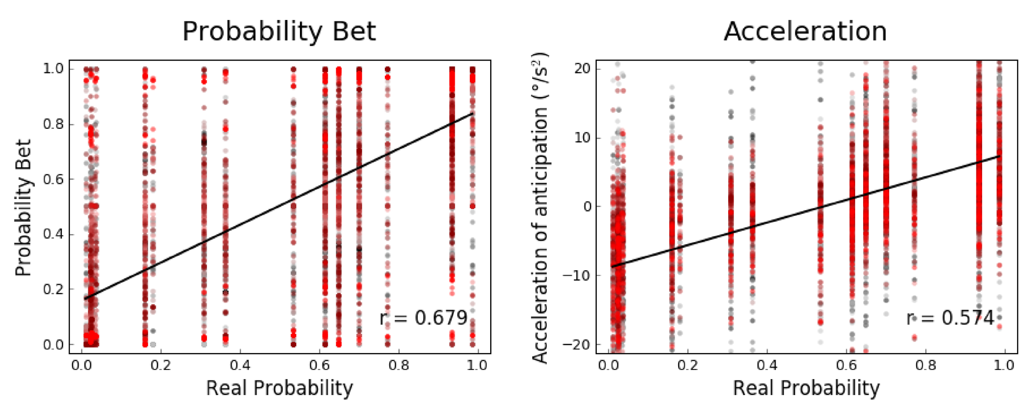
Results

Eye mouvements recording and the Bet

Example of results obtained during the bet and the recording :



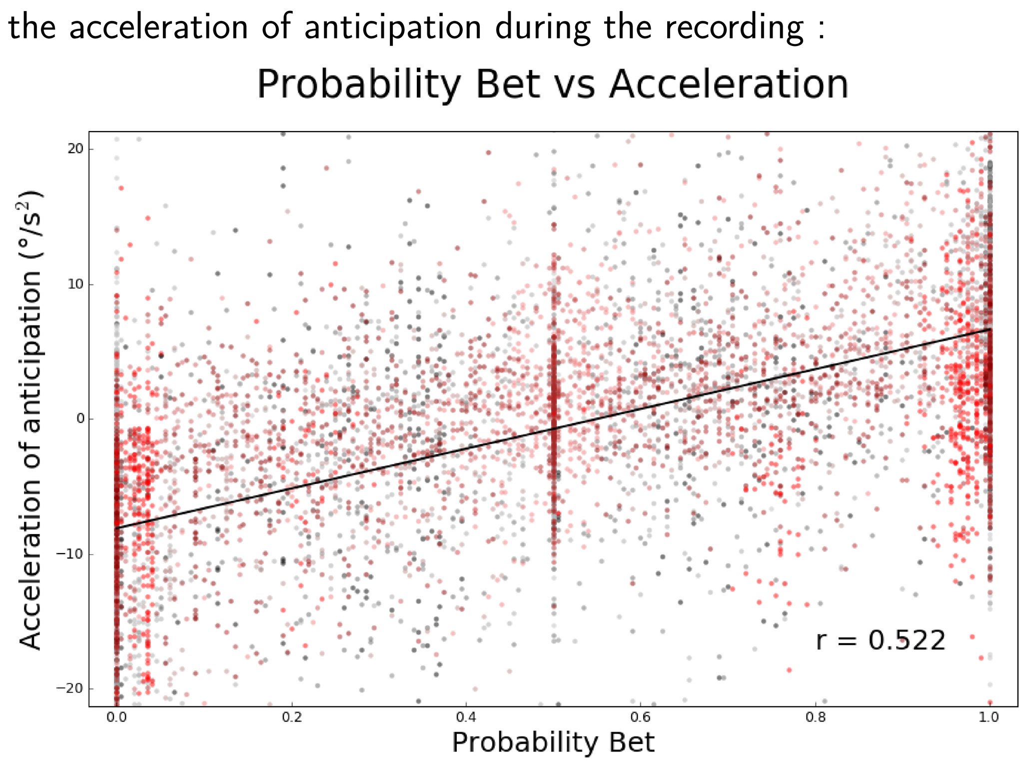
Let's plot the value of the bet (probability bet) and the acceleration of anticipation (slope of aSPEM) as a function of the real probability at every given trial :



Which give a strong and positive Pearson coefficient.

Relating the Bet to the Recording

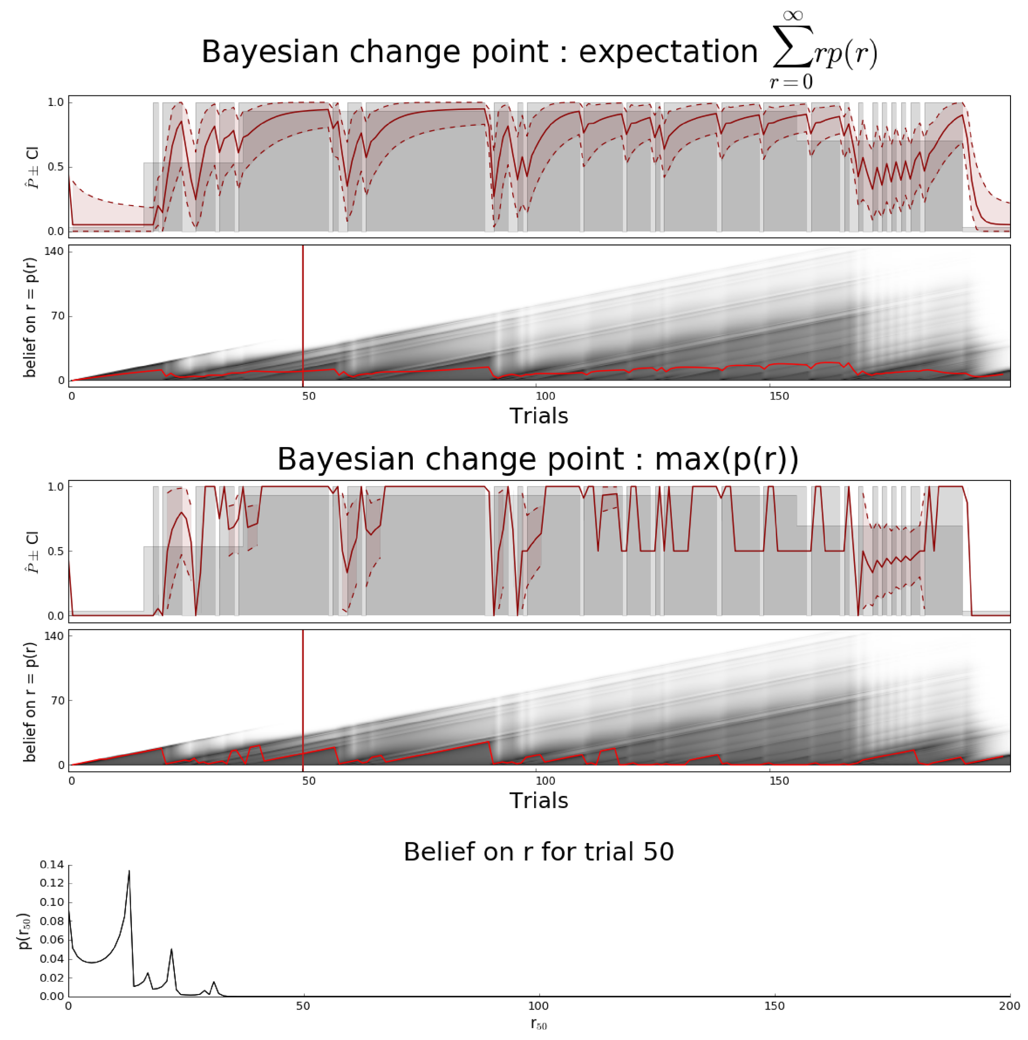
We now compare the value of bet during the bet experiment with the acceleration of anticipation during the recording :



Model

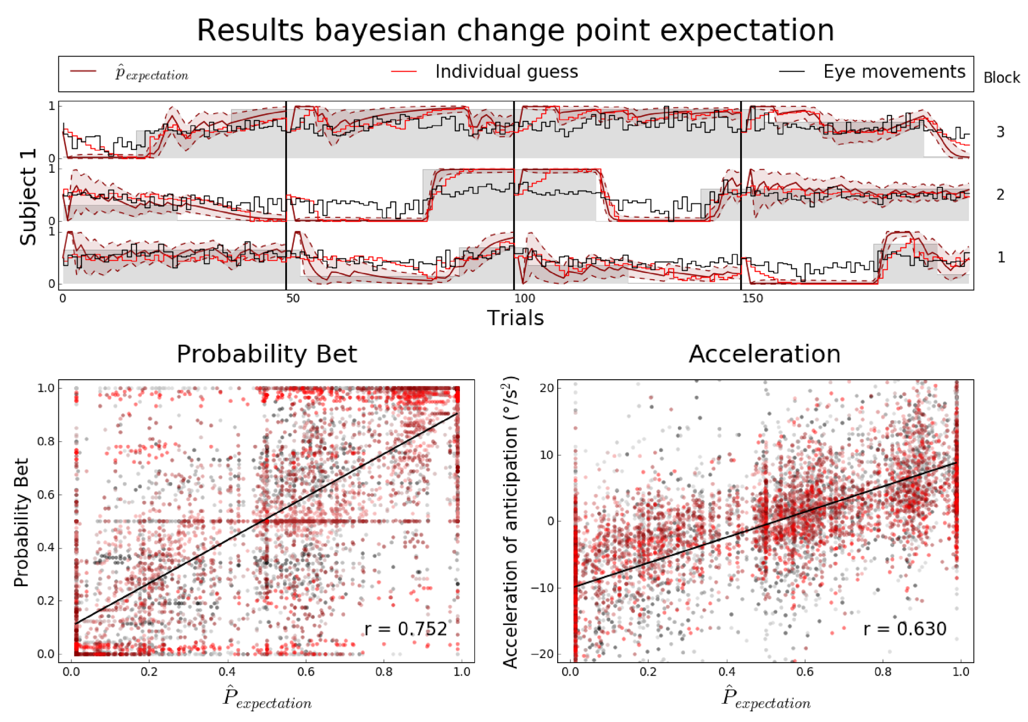
Bayesian change point model

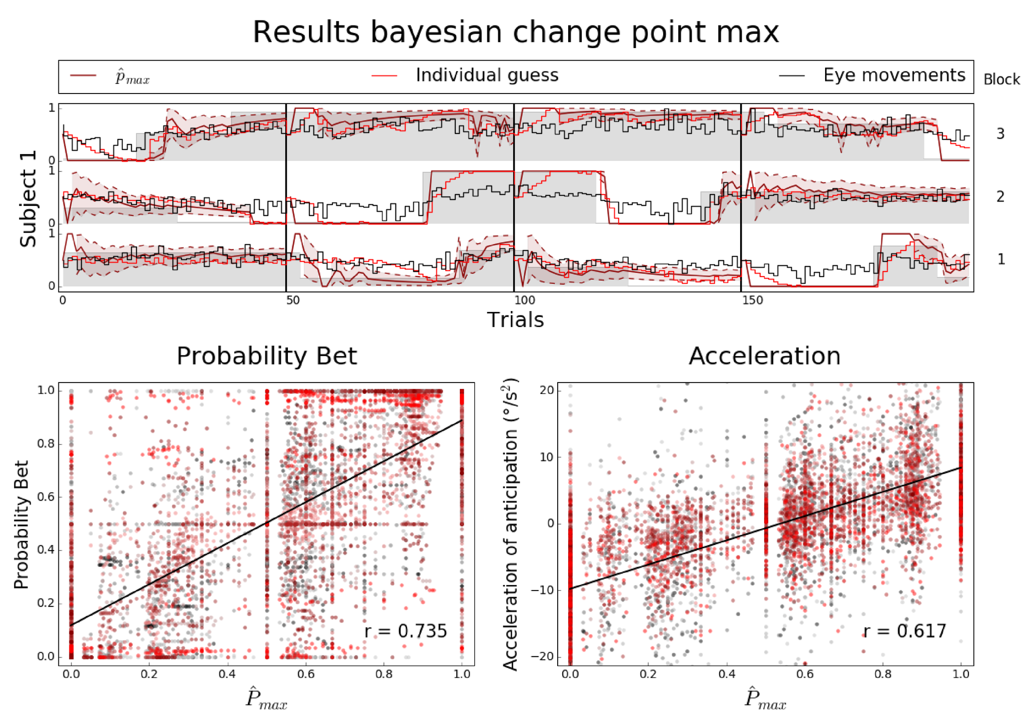
We have designed an agent adapted the Bayesian Online Change-point Detection model [**AdamsMackay2007**]. This model uses a latent variable r which represents the length of the current interval during which motion-direction probability ($\hat{P}$) has not changed. The agent infers at each trial the likelihood of r and then deduces the optimal $\hat{P}$ (we used the expected value and the max as read-outs) and the uncertainty associated to it. We simulated the model across our experimental sequences, as illustrated by the example for the third block.



Comparing the Bayesian change point model with humans

We now compare the individual guesses during the bet experiment and the acceleration of anticipation during the eye movement recordings with the model simulations :





Conclusions

- There is a strong correlation between the real probability and the value of the bet,
- there is a stong correlation between the strength of anticipation and the probability of the process,
- we have developed a Bayesian model of an agent estimating the probability of changing points. This allows to dynamically infer the direction probability and directly compare model and human behaviour.

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