# LGBIO2060: Project 1 – Instructions

You are working in a famous lab of neurosciences, and you focus on the integration of sensory information from the body. Few weeks ago, you conducted an experiment to investigate whether humans use a Bayesian process to integrate their sensory information coming from vision and prior knowledge. Now that you have collected the data, you are asked to analyze the data and to provide graphs to support your conclusion on this research question.

## 1) *Context*

The human body sensors provide noisy and imperfect information. The brain combines this information, coming from different modalities, to produce a unique estimation of the state (for example, the position of the body). The Bayesian theory offers a probabilistic approach to optimally combine the different pieces of information. The brain would need to represent the uncertainty of the different modalities (vision, proprioception, prior knowledge…). As the uncertainty of one modality increases, the brain would rely more on other modalities. In the following experiment, the uncertainty associated with the visual feedback was modulated to assess the validity of this assumption.

## 2) *The experiment in details*

For this experiment, participants were asked to perform a series of reaching movements (i.e., movement from a starting point A to a target B with the hand). A screen was placed above their arm to hide their hand. The target and the position of the hand was represented as a dot on the screen. This way, the visual feedback on the hand position can be easily manipulated:

1. Visual feedback was only provided briefly, midway through the movement.
2. The visual feedback was shifted to the right compared to the actual position of the hand. This shift was randomly drawn from a Gaussian distribution with a mean of 1 cm and standard deviation of 0.5 cm. The instruction given to the participant was that the cursor representing the hand should reach the target, not their true hand position. Therefore, they had to adapt to this shift.
3. The reliability of the feedback was also manipulated: the position of the hand was either represented by a dot ( = minimal uncertainty), a medium size cloud of dots, a large cloud of dots or no feedback at all ( = infinite uncertainty).

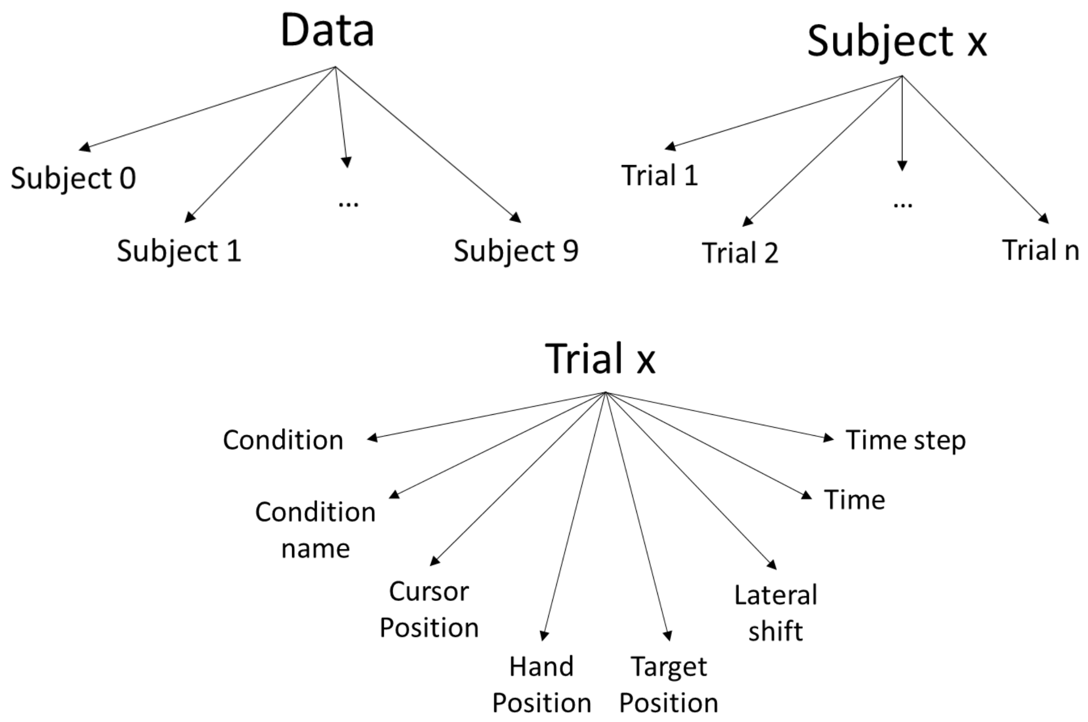
At the end of the movement, but only for clear feedback trials, visual information about the position of the finger was provided. This way, trial after trial they could learn the shift distribution to constitute a prior knowledge.

The participants were trained with 1000 trials (i.e. 1000 reaching movements, with different shift and different reliability of feedback) to ensure a correct learning of the shift distribution. Then, they performed again 1000 trials. The dataset you will analyze here contents these 1000 last trials and is available on Moodle.

To make sure you understand correctly the setup of this experiment, watch the video named "LGBIO2060_Project1" on Moodle, showing a similar experiment (but slightly different) with the same setup.

*3) The dataset*

The dataset is called "*Project 1 - Dataset*" and is available on Moodle. The dataset is structured as a dictionary, meaning that you can call the variables contained in it with keys. The main dictionary contains 1 dictionary for each subject. Subjects are again subdivided into different dictionaries representing each **valid** trial (pay attention to the trial numbering) of this subject. Each trial contains several variables describing the trial. Graphically this looks like this:




Some details about the variables:

*Condition*: integer informing the kind of feedback given to the subject (either 1, 2, 3 or 4)

*Condition_Name*: string informing the kind of feedback given to the subject: "shift", "small blur", "large blur" or "occluded".

*CursorPos*: list of 200 numpy arrays, one for each time step. In each array, one line gives the x,y and z coordinates of one dot of the feedback given to the subject on the screen. If the feedback is a cloud of dot, the array is size (25,3), else the array is size (3,). When the feedback is occluded, the arrays are filled with 'nan'.

*HandPos:* Array of size (200, 3) giving the hand position (x, y, z-coordinates) at each time steps

*LateralShift:* value in cm giving the lateral shift between the hand position and the feedback given through the screen.

*TargetPos:* Array of size (200, 3) giving the target position (x, y, z-coordinates) at each time steps.

*Time: Array of float of size (200,).*

*TimeStep: Array of int of size (200,).*

4) *Questions*

**Q1) Explore the data.**

When you are confronted with a new dataset, you need to get more familiar with it. Analyze its structure, make sure to understand the variables involved, etc.

A) What are the variables the experimenter control? What changes over the different trials? What variables are the results of the experiment, what is measured?
B) Plot some relevant figures that represent the data. For example, it could be typical trials for one subject, it could a mean trajectory over the subjects, over the conditions... Justify your choice.

**Q2) Answer the research question: "Do the subjects use a Bayesian strategy to estimate the shift or a naïve compensation?"**

To answer this question, let's think step by step. A Bayesian strategy implies the use of a prior knowledge, with a distribution around a certain mean, with some variability, and the use of a likelihood.

A) First, identify the prior distribution and the likelihood. Do these distribution change according to the trials?
B) In the case you use a Bayesian strategy, compute the shift estimation for a true shift of 1.5 cm with feedback associated with a variance of 0.1 cm. With this shift estimate, what will be the deviation from target at the end of the movement (considering that the execution of the movement perfectly reflects the position that the subject aims)?
C) How will evolve this error (deviation from target) for different shifts? Sketch a graph and describe it qualitatively.
D) How would this graph change if the variability of the feedback decreases/increases? Add two traces on the previous graph (corresponding to a more reliable feedback and a less reliable feedback).
E) Build these theoretical graphs with the experimental data and discuss the results. Check that the theory applies to each condition and each subject.
F) In comparison with a Bayesian strategy, the naïve strategy would consist in ignoring the prior and only use the feedback. How would evolve the error with this strategy? Which strategy is better? Why?

**In practice, you must submit your answers for October 26$^{th}$. We ask you to deliver your answers, the graphs and the python code used to do the different computations and graphs. You can either submit a notebook which incorporate everything (text answers, graphs, code) or .py file with an annexed report. Your answers can be either in English or French. Few days after the submission, you will have the opportunity to defend your answers during a short discussion (10 minutes) with one of the teaching assistants.**