Modeling 3 – Project 2025-2026

Personality traits and guidance for robot-assisted motor learning.

After traumatic events such as a stroke, patients that have partially lost ability to move may need to go through rehabilitation. Modern technologies are currently being developed to better support rehabilitation, including robot-based techniques. This refers to situations where the robot helps the patient to practice the movement again.

In some cases, it is even possible that the robot helps the human, by offering guidance (for example, applying a force in the right direction). It is still an open question whether such a guidance can actually help the patient, for example by reducing training time or improving movement accuracy.

For this experiment, a number $n = 100$ participants were recruited. The task studied here is to hit a target on a wall with a pendulum in a virtual world using a robotic device (that might or might not provide guidance to the user), to simulate a rehabilitation scenario. The game is composed of 20 targets that arrive on the screen one after the other; each target has its own position on the wall, and they always arrive in the same order each time the game is played and for all participants. People could feel the movement of the pendulum when holding the device. They could see on the screen the absolute value of the error, denoted by |Error|, defined as the distance (in the virtual world) between the center of mass of the pendulum and the center of mass of the target. This is represented on Figure 1 below.

It is conjectured that the efficiency of the guidance may be related to personality traits: depending on their personality, people may be reacting more positively or more negatively to the guidance applied to them. One of the goals of the current study is to answer the following questions: can robot-assisted motor training actually help people to learn better? Does this improvement in performance depend on personality traits?

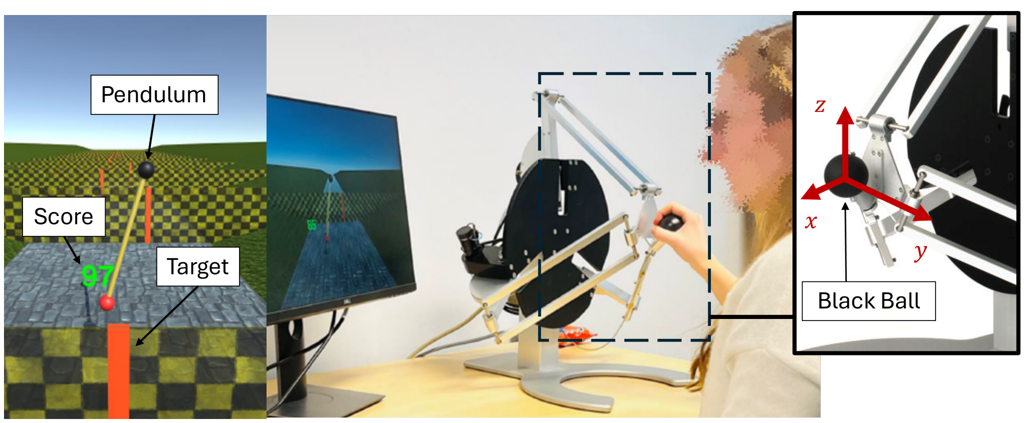

Figure 1: The experimental setup (center) consists of the screen and the gaming device. Left: Game screenshot with the pendulum, walls in black and yellow, targets as vertical red lines, and the score in green numbers. Right: The gaming device could be controlled by holding the black ball attached to the robot end-effector.

The experimental protocol is the following. For each participant $i = 1, \dots, n$:

1. Participant i is randomly assigned to either the Control group ($\text{Group}_i = C$) or to the Experimental group ($\text{Group}_i = E$).

2. The participant i fills out a personality questionnaire. This gives the following personality scores (between 0 and 100):

   - AC_i ("Achiever" score): reflecting a preference for really getting high scores;
   - FS_i ("Free Spirit" score): reflecting a preference for exploration;
   - TC_i ("Transform of Challenge" score): reflecting participant's tendency to transform "challenging" situations, into personally motivating ones;
   - TB_i ("Transform of Borendom" score): reflecting participant's tendency to transform "boring" situations, into personally motivating ones.

3. The participant gets familiar with the device and the gaming environment.

4. The participant plays the game once, going through the 20 different targets of the game. The score is not recorded at this moment.

5. The participant plays the game twice; these are called Baseline ("BL") measurements:

   (a) For the first game, for $k = 1, \dots, 20$, the absolute error for the k-th target is denoted by $|\text{Error}|_{i,\text{BL},1,k}$.

   (b) For the second game, for $k = 1, \dots, 20$, the absolute error for the k-th target is denoted by $|\text{Error}|_{i,\text{BL},2,k}$.

6. The participant is informed that they might or might not be assisted during training, in order to promote active participation. For this, they played the game 30 times, each going successively over all the 20 targets. If the participant belong to the Experimental group ($\text{Group}_i = E$), they received guidance from the gaming device for most of the games [1]. The score is not recorded during this training phase.

7. The participant takes a short (around 10 minutes) break.

8. The participant plays the game twice (without any guidance); these are called Short-term retention ("STR") measurements:

   (a) For the first game, for $k = 1, \dots, 20$, the absolute error for the k-th target is denoted by $|\text{Error}|_{i,\text{STR},1,k}$.

   (b) For the second game, for $k = 1, \dots, 20$, the absolute error for the k-th target is denoted by $|\text{Error}|_{i,\text{STR},2,k}$.

9. A few days later, the participant come back to play the game twice (without any guidance); these are called Long-term retention ("LTR") measurements:

   (a) For the first game, for $k = 1, \dots, 20$, the absolute error for the k-th target is denoted by $|\text{Error}|_{i,\text{LTR},1,k}$.

   (b) For the second game, for $k = 1, \dots, 20$, the absolute error for the k-th target is denoted by $|\text{Error}|_{i,\text{LTR},2,k}$.

The outcome of the whole experiment is two datasets: one with the personality traits data and one with the game (error) data.

[1] They do not receive guidance for all the games, so that they do not get used (too much) to the guidance.

Week 1. In the first week, you will analyze the personality questionnaire dataset. Plot histograms of the random variables AC, FS, TC, TB and decide which parametric family of distributions will be appropriate to model this data. Estimate the parameters of the proposed distributions and apply a goodness-of-fit test to see if the proposed distribution is appropriate to model the data.

Week 2. For $i = 1, \dots, n$ and for $Stage \in \{\mathrm{BL}, \mathrm{STR}, \mathrm{LTR}\}$, compute the average absolute error of participant i at this stage given by

$$\mathrm{AveAbsError}_{i,Stage} := \frac{1}{40} \sum_{k=1}^{20} |\mathrm{Error}|_{i,Stage,1,k} + |\mathrm{Error}|_{i,Stage,2,k}.$$

Are $\mathrm{AveAbsError}_{i,\mathrm{BL}}$, $\mathrm{AveAbsError}_{i,\mathrm{STR}}$, and $\mathrm{AveAbsError}_{i,\mathrm{LTR}}$ significantly different between between participants of the Control and the Experimental group?

Does the average error reduces after the training, compared to the baseline? You will answer this both for the short-term and the long-term retention. We define the short-term and long-term learning effects by

$$\begin{aligned}
\mathrm{LearningEffect}_{i,\mathrm{STR}} &:= \mathrm{AveAbsError}_{i,\mathrm{BL}} - \mathrm{AveAbsError}_{i,\mathrm{STR}}, \\
\mathrm{LearningEffect}_{i,\mathrm{LTR}} &:= \mathrm{AveAbsError}_{i,\mathrm{BL}} - \mathrm{AveAbsError}_{i,\mathrm{LTR}},
\end{aligned}$$

for participant $i = 1, \dots, n$. Are $\mathrm{LearningEffect}_{i,\mathrm{STR}}$, and $\mathrm{LearningEffect}_{i,\mathrm{LTR}}$ significantly different between participants of the Control and the Experimental group?

Can we say that the guidance helped participants to learn better on average?

Week 3. We now want to know whether the personality traits have an impact on the performance and the learning of the participants. For each $s \in \{\mathrm{BL}, \mathrm{STR}, \mathrm{LTR}\}$, select only observations for which $Stage = s$, and fit the linear regression model

$$\mathrm{AveAbsError}_{i,s} = \beta_{0,s} + \beta_{1,s}\mathrm{AC}_i + \beta_{2,s}\mathrm{FS}_i + \beta_{3,s}\mathrm{TC}_i + \beta_{4,s}\mathrm{TB}_i + \varepsilon_{i,s},$$

where $\beta_{0,\mathrm{BL}}, \dots, \beta_{4,\mathrm{BL}}, \beta_{0,\mathrm{STR}}, \dots, \beta_{4,\mathrm{STR}}, \beta_{0,\mathrm{LTR}}, \dots, \beta_{4,\mathrm{LTR}}$ are coefficients to be estimated and $\varepsilon_{i,s}$ is the noise term.

Fit the linear regression

$$\begin{aligned}
\mathrm{AveAbsError}_{i,s} = {} & \beta_{0,s} + \beta_{1,s}\mathrm{AC}_i + \beta_{2,s}\mathrm{FS}_i + \beta_{3,s}\mathrm{TC}_i + \beta_{4,s}\mathrm{TB}_i \\
& + \big(\beta_{5,s} + \beta_{6,s}\mathrm{AC}_i + \beta_{7,s}\mathrm{FS}_i + \beta_{8,s}\mathrm{TC}_i + \beta_{9,s}\mathrm{TB}_i\big)\mathbf{1}_{\{\mathrm{Group}_i = E\}} \\
& + \varepsilon_{i,s}.
\end{aligned}$$

What is the interpretation of these coefficients? Explain the need for this model compared to the simpler model:

$$\mathrm{AveAbsError}_{i,s} = \beta_{0,s} + \beta_{1,s}\mathrm{AC}_i + \beta_{2,s}\mathrm{FS}_i + \beta_{3,s}\mathrm{TC}_i + \beta_{4,s}\mathrm{TB}_i + \beta_{5,s}\mathbf{1}_{\{\mathrm{Group}_i = E\}} + \varepsilon_{i,s}.$$

Explain for which type of personality traits the guidance is favorable, and for which kind of personality traits the guidance degrades the learning.

Week 4. Perform a power analysis to know whether the sample size is sufficiently large for the difference between the control and experimental group to be detected with at least 80% probability.

Week 5. Draft report.

A detailed description of the above questions constitutes the minimum results that you have to obtain in this project. You are encouraged to consider extensions of these questions (**Weeks 6-7**), which can include:

- Since $|\text{Error}|$ is strictly positive, one may want to consider *multiplicative* effects instead of *additive* effects. This amounts to transforming $|\text{Error}|$ to $\log_{10}|\text{Error}|$. Do the models get better with this transformation?
- Extending the linear regression models with more features and interaction terms.
- Using the data of all errors directly instead of aggregating them. This actually helps to increase the statistical performance, but at the price of using more advanced statistical models such as linear mixed-effects regression models. A related research question is to know whether participants improved during each stage (as they advance further through the game).
- Studying dependence between personality traits.