Applied Neuroscience
Exercise 1: Motor Learning

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In motor learning studies, scientists are trying to find mathematical models that could describe the behavioral data accurately. On the other hand, there are some behavioral phenomena that could be used as quality measurement for validity of models. In this exercise, the two phenomena, i.e., **Savings** (section 1) and **Spontaneous Recovery**(section 2) will be evaluated through two different models. The models were analyzed through different experiments in [1].

- **Single State Model** which has one single time-constant

$$x(n+1) = A \cdot x(n) + B \cdot e(n) \tag{1}$$

  where $x(n)$ is motor output on the nth trial, A is retention rate, and B is learning rate, and

- **Two State (Gain-Independent) Model** which has multi-rate time constants

$$x_1(n+1) = A_f \cdot x_1(n) + B_f \cdot e(n) \tag{2a}$$
$$x_2(n+1) = A_s \cdot x_2(n) + B_s \cdot e(n) \tag{2b}$$

  Where $B_f > B_s, A_s > A_f, x = x_1 + x_2$

Error is always defined as follows:

$$e(n) = f(n) - x(n) \tag{3}$$

Where $f(n)$ is the environment state (disturbance or perturbation) on trial nth.

To simulate the models, we use the following values from the Table

Single-State Model	Multi-Rate Model
$A = 0.99$	$A_f = 0.92$, $A_s = 0.996$
$B = 0.013$	$B_f = 0.03$, $B_s = 0.004$

1 Savings

Savings is rather a new phenomena in motor learning. Recently different groups have done experiments to analyze the savings effect in motor adaptation tasks. Describe the savings. What are the main parts of a savings experiment? (you can also use the paradigm in this section for demonstration)

In order to observe the savings behavior, use the following paradigm for 800 trials:

$$f(n) = \begin{cases} 0 & 0 \leq n < 50 \\ 1 & 50 \leq n < 401 \\ -1 & 401 \leq n < n_0 \\ 1 & n_0 \leq n < 801 \end{cases} \tag{4}$$

Where $n_0 = 431$ for Single-state model and $n_0 = 418$ for Multi-rate model. Plot adaptation vs. trials for both models. Explain and show the savings. Why the second model can exhibit faster relearning? Why different n_0 have been chosen for two models?

Another advantage of the Multi-rate model is that the effect of the wash-out trials is discernible in savings. Thus, insert wash-out trials ($f(n) = 0$) with variable length (from one trial to 300 trials) between de-adaptation and re-adaptation trials. To visualize the effect of these null trials, plot savings vs. number of wash-out trials. There are many different ways to estimate a value for savings. The simplest method is to calculate the percentage of improvement of adaptation on 30th trial of relearning to 30th trial of initial learning.

2 Spontaneous Recovery

Spontaneous recovery is widely used in classical conditioning (Pavlovian conditioning) which was introduced by Ivan Pavlov. Describe the spontaneous recovery term.

For spontaneous recovery to become apparent in simulations, error clamp trials are implemented. Describe what an error clamp is and why it is used in experimental studies and how do you simulate an error clamp.

For spontaneous recovery, use the following paradigm for 800 trials:

$$f(n) = \begin{cases} 0 & 0 \leq n < 50 \\ 1 & 50 \leq n < 401 \\ -1 & 401 \leq n < n_0 \\ \text{error clamp} & n_0 \leq n < 801 \end{cases} \tag{5}$$

Where $n_0 = 431$ for Single-state model and $n_0 = 418$ for Multi-rate model. Plot adaptation vs. trials for both models. Which model can exhibit spontaneous recovery? Why?

[2] has shown the jump-up facilitation in saccade eye movements. Thus, the possibility of such behavior can be examined here too.

To simulate this action, use the following paradigm for 800 trials:

$$f(n) = \begin{cases} 0 & 0 \leq n < 50 \\ 1 & 50 \leq n < 401 \\ -1 & 401 \leq n < n_0 \\ \text{error clamp} & n_0 \leq n < 551 \\ 1 & 551 \leq n < 801 \end{cases} \tag{6}$$

Where $n_0 = 431$ for Single-state model and $n_0 = 418$ for Multi-rate model. Plot adaptation vs. trials for both models. Which model can exhibit jump-up? Why?

References

[1] Maurice A Smith, Ali Ghazizadeh, and Reza Shadmehr. Interacting adaptive processes with different timescales underlie short-term motor learning. *PLoS biology*, 4(6):e179, 2006. https://doi.org/10.1371/journal.pbio.0040179.

[2] Yoshiko Kojima, Yoshiki Iwamoto, and Kaoru Yoshida. Memory of learning facilitates saccadic adaptation in the monkey. *Journal of Neuroscience*, 24(34):7531–7539, 2004. http://www.jneurosci.org/content/24/34/7531.long.