

Exercises Motor adaptation

1. Two state-model (Smith et al. 2006)

Figure 1A of the Smith paper shows a paradigm for a relearning experiment. The rightmost panel of Figure 1B shows the predictions of the two-state model for this paradigm.

- a. Implement the two-state model and simulate the paradigm shown in Fig. 1A. The parameter values used are given in the Materials and Methods section of the paper. The numbers of trials in the four phases of the experiment are 50, 350, 25 and 275, respectively. Are you able to reproduce the rightmost panel of Fig. 1B?
- b. Repeat the simulation above four times, each time with one of the parameter values changed. Use the following changes: double the learning rates, and reduce the retention factors by 10%. Compare the results to the results of your simulation with the baseline values. Explain the differences.

2. Two state-model (Smith et al. 2006) applied to stochastic perturbations

The study of Fernandes et al. (2012) examined generalization of adaptation to stochastic visuomotor rotations. Subjects first adapted to a stochastic 30 deg visuomotor rotation. This means that the perturbation was not constant, but Gaussian white noise was added to it, with a standard deviation (SD) of 0, 4 or 12 deg. The authors then examined how generalization depended on this SD.

In this exercise we do not look at generalization, only at the adaptation to the stochastic visuomotor rotations. The authors found that as the SD of the perturbation increased, adaptation was less complete. Here we will examine whether this result agrees with the predictions of the two-state model.

- a. Run simulations of the two-state model for the situation in the Fernandes paper: 80 baseline trials with no perturbation, followed by 240 trials with a stochastic perturbation with a mean of 30 deg and an SD of 0, 4 or 12 deg. Use the same parameter values as in exercise 1a.
- b. Fit (single) exponential curves of the form $x(t) = A*(1 - \exp(-t/\tau))$, with τ the time constant and A the asymptote, to the adaptation curves. Do single exponentials give a good description of the adaptation curves? Why?
- c. Which function will better fit the adaptation curves? Fit also this function to the simulated adaptation curves.
- d. To determine how complete adaptation is, one can look at the asymptote of the function fitted to the adaptation curves at c. Determine the value of this asymptote for each of the three simulations. Do they follow the pattern found by Fernandes et al.?
- e. Looking at a single simulation for each SD is not a reliable method to study whether the asymptote of the adaptation curve depends on this SD. What would be a more reliable method? Repeat your analysis using this more reliable method.

3. Parallel one-fast, multiple-slow process model (Lee & Schweighofer 2009) and long-term savings

The parallel one-fast, multiple-slow process model can explain savings, also after a long block of washout trials, see Fig 7 in the paper by Lee & Schweighofer (2009). However, the reason why this model reproduces this

phenomenon, whereas the two-state model doesn't, is not so obvious. The purpose of this exercise is to understand why the Lee & Schweighofer model can explain long-term savings.

- a. Simulate the parallel one-fast, multiple-slow process model for exactly the situation depicted in Fig 7 in Lee & Schweighofer (2009). The lengths of the various phases of the experiment are given in the figure caption, and the parameters are given in the Materials and Methods section. Plot the output of the model as a function of the trial number, and plot also the values of all the internal states.
- b. To understand why the model explains long-term savings, it can be useful to compare its predictions to those of the two-state model. Simulate therefore also the two-state model for this experiment, using the same parameter values as for the parallel one-fast, multiple-slow process model. Plot the output of this model, as well as its internal states, in the figure that you made in a.
- c. Carefully analyze the differences between the predictions and internal states of both models. What's the crucial difference between the models that explains that only the parallel one-fast, multiple-slow process model can explain long-term savings? Hint: if you have trouble finding the crucial difference, vary the lengths of the various phases of the experiment.

4. Error-dependent learning rate model (Herzfeld et al. 2014)

Figure 4 of the paper by Herzfeld et al. (2014) shows the results of several conditions of a visuomotor adaptation experiment. Although these results confirm the predictions of the error-dependent learning rate model, the actual model predictions are not shown. In this exercise we will determine these model predictions.

- a. To use this model, we first have to set up the population code that represents the error-sensitivity function. We use 20 basis elements, equally spaced between -40 and +40 deg, and with a standard deviation of 3 deg. We initialize the model such that the error sensitivity is 20% for a large range of errors. Determine the weights w that are needed for this.
- b. Simulate the model for the ANA paradigm shown in Fig. 4A of Herzfeld et al. (2014). The lengths of the four phases in the experiment are 90, 90, 120 and 90 trials, respectively. Use the following parameter values: $a = 1$, $\beta = 0.1$.
- c. To determine time constants of the adaptation curves in Fig. 4D, Herzfeld et al. fitted (single) exponential functions to the observed learning and relearning curves. Determine the time constants for the predicted adaptation curves. Do they match the values shown in Fig. 4D?
- d. Simulate the model also for the BNA paradigm shown in Fig. 4A. Determine also the time constants for adaptation in this paradigm, and compare these to the values shown in Fig. 4D.
- e. Verify whether the two-state and the parallel one-fast, multiple-slow process model predict savings in the BNA paradigm.
- f. Figure 4A also shows the paradigm B(wait)NA. The model as formulated by Herzfeld et al. is not able to make predictions for this paradigm. Why? How could the model be extended to make this possible?