Matlab Seminar, winter semester 2015-16

Final Project: Multisensory Integration

Consider an experiment in which participants are instructed to estimate the size of an object using information from both visual and tactile modalities (Ernst & Banks 2002). Critically, the participants can only estimate the size in each modality with uncertainty. The research question of the Ernst & Banks (2002) paper was how participants integrate both uncertain sources of information to estimate the object size. Ernst & Banks used a mathematical model to predict participants' responses: They assumed that a participant('s brain) measures the visual size with uncertainty. They described this uncertain representation of the brain as a normal distribution $x_v \sim N(\mu_v . \sigma_v^2)$ where x_v is the size inferred from the visual observation, μ_v is the mean, and σ_v^2 is the variance. For the haptic source, they used an analogous normal distribution $x_h \sim N(\mu_h . \sigma_h^2)$. Ernst and Banks now assumed that both the visual and haptic uncertain information are integrated by the brain according to a so-called Maximum-likelihood estimate to form a combined visual-haptic size representation $x_{vh} \sim N(\mu_{vh} . \sigma_{vh}^2)$. Importantly, the mean and variance of this combined estimate are described by:

$$\sigma_{vh}^2 = \frac{\sigma_v^2 \sigma_h^2}{\sigma_v^2 + \sigma_h^2}$$

$$\mu_{vh} = \sigma_{vh}^2 \left(\frac{\mu_v}{\sigma_v^2} + \frac{\mu_h}{\sigma_h^2}\right)$$

In summary, Ernst and Banks derived a formula for how one can predict a participant's multisensory size estimate given knowledge about how the participant responds both unimodal (i.e. visual and haptic) size stimulus separately. In their paper they used behavioural measurements to show the accuracy of these predictions.

In this project, you will illustrate these theoretical predictions and compare them with (simulated) behavioural responses. In the given task, you will generate the results from the experiment with multiple participants and compare them with theoretical predictions.

Note: In this project you will need to use functions from the Matlab statistics toolbox and other external sources. In case you are explicitly asked to use a specific function and you do not have that function in your installed MATLAB version, you can use the source of these functions provided in the MATLAB exchange website:

- normcdf function source
- shadedErrorBar function source

Suppose we have the behavioural data of a visual-haptic discrimination task similar to (Ernst & Banks 2002), where participants had to indicate whether the presented object was taller than a baseline object using both visual and haptic information. The difference between heights of the presented object and the baseline object was chosen randomly from 40 possible values between 3 mm to 12.75 mm (step size was 0.25). Each height difference value was presented in 10 trials, so that each participant performed the task 400 times. The results are stored in an Excel file (.csv) where each row contains the data for one trial and the four columns indicate participant number, trial number, height

difference between the presented object and the baseline object, and the response of the participant in the respective trial (0 for "shorter" and 1 for "taller").

(a) Load the data from the given csv file and store them in a 3D matrix where each page corresponds to results of a single participant. Note that you must not change the csv file. (Hint: use the csvread function of MATLAB).

(b) Plot the psychometric curve for all participants within one plot, where the x-axis shows the height difference between the two objects, and the y-axis corresponds to the proportion of trials in which that subject perceived the presented object as "taller".

(c) Plot the mean psychometric curve for all five participants with the shaded error-bar showing the standard error ($\sigma_{vh}/\sqrt{\mathrm{N}}$, where N is the number of participants). Axes are similar to the plot generated in the last part. Also, calculate the 50% sensory threshold for the psychometric function and plot it along with the curve as a horizontal line. (Hint: use the shadedErrorBar function provided to you).

(d) Plot the theoretical cumulative normal distribution (using nomrcdf function) for combined visual and haptic information with parameters $\mu_v = 5$, $\sigma_v^2 = 5$, $\mu_h = 10$, $\sigma_h^2 = 5$ (using the formulas given above) over the mean psychometric function to evaluate how the model prediction of the psychometric function can fit the experimental data.