02458 Cognitive Modeling Final Exam 2021

- Time of exam: The exam begins 9 am on the 9*th* of december 2021. The exam ends at 1 pm (2 pm for special needs students).
- Exam form: Online written exam. All aids are allowed including internet resources. You may not communicate with others until the exam is officially completed for all students at 2:15 pm.
- Submission: Please submit your answers in pdf format.
- You may receive notifications over DTU Inside regarding the exam during the exam. You are therefore advised to have your student email or phone open during the exam.

Problem 1: The late MLE model of audiovisual integration (20 points)

Andersen (2015) tested the FLMP and the early MLE model. In Homework 2 we reproduced some of these results by fitting the two models to a data set. Andersen also tested other models including the late MLE model. In this problem we will fit the late MLE model, to the same data. The data also comes with this exam in files DatSub1-5.txt. Please, refer to section 1.1 in the first part of Homework 2 for a description of the data.

The early MLE model has two components. The first component is that observers base their responses to auditory and visual stimuli on an underlying auditory and visual continuous internal representations, S_A and S_V. The late MLE model shares this component with the early MLE model. The second component of the early MLE model is that audiovisual integration is based on the auditory and visual continuous internal representations. This late MLE model does *not* share this component with the early MLE model. In the late MLE model, audiovisual integration is based on the same mechanism as in the FLMP.

Reference: Andersen, T. S. (2015). The early maximum likelihood estimation model of audiovisual integration in speech perception. The Journal of the Acoustical Society of America, 137(5), 2884–2891.

- How many free parameters does the late MLE model have? What do they signify?
- Write the full equations expressing the auditory, visual and audiovisual response probabilities as a function of the late MLE model's free parameters
- Fit the late MLE model to the data that comes with this exam (same data as in Homework 2). Fit the model by finding the maximum likelihood estimate of the free parameters just as you did for the early MLE model and the FLMP in Homework 2.
- Provide a table of the of the maximum likelihood estimate of the free parameters for each subject. Also list the values for the negative logarithm of the maximum likelihood for each subject.
- Compare the fit of the late MLE with the fit of the early MLE listed in the table below. Which model fit better? Why is this comparison better than a comparison of the FLMP with the early MLE model if we are interested in determining how the subjects integrate audiovisual information?

Subject	1	2	3	4	5
Early MLE negative log likelihood	72.80	55.08	69.41	67.21	53.55

Problem 2: Signal detection theory and the psychometric function (20 points)

Using a deep neural network researchers believe they can synthesise images that are more or less exciting. In order to test their hypothesis, they present two groups of 50 images each to an observer. One group of images contain images that they believe should not be exciting and the other group contain images that they believe should be very exciting. The observer responds on a excitement scale from 1 to 5 where 5 is maximally exciting. The results are listed in the table below.

Response category	1	2	3	4	5
Response counts for not exciting images	4	15	22	7	2
Response counts for exciting images	2	4	8	10	26

- What are the parameter values for the parameters of the unequal variance receiver operating characteristics (ROC) for this experiment?
- Rebin the data by pooling responses in response categories 2-5 into a single response category. Calculate the sensitivity d' for the rebinned data. Rebin the data by pooling responses in response categories 1-4 into a single response category. Calculate the sensitivity d' for the rebinned data. Interpret your results.

Bayesian observer theory (20 points)

A cat sits in complete darkness in front of two holes 20 cm apart. The holes are tiny. The cat knows the location of the holes. It also knows that for every mouse that comes out of the left hole three mice comes out of the right hole. The occurrence of mice coming out of the holes seems quite random. The cat now hears a mouse squeak. The location of the mouse appears (to the cat) to be between the holes: 5 cm from the left hole and 15 cm from the right hole. There are no mice outside of the holes, so the cat knows that the sound must come from one of the holes.

The cat's auditory system is not quite accurate so its estimate of the location of a mouse squeak varies around the true location as a normal distribution with a standard deviation of 10 cm.

- Which hole will the cat target given that it behaves according to a maximum a posteriori probability decision rule? Describe how you arrived at the result in detail.

Imagine that the cat did not sit in darkness so that the cat could also see the mouse. The visual location of the mouse appears (to the cat) to be almost right between the holes: 9.9 cm from the left hole and 10.1 cm from the right hole. The cat's visual system is more accurate than the auditory system so its estimate of the location of a mouse squeak varies around the true location as a normal distribution with a standard deviation of 2 cm. The cat integrates information from the auditory and visual systems according the MLE model.

- Which hole will the cat target given that it behaves according to a maximum aposteriori probability decision rule? Describe how you arrived at the result in detail.

Problem 4: Linear encoding of faces (30 points)

Researchers have used Principal Component Analysis (PCA) to reduce the number of dimensions of images with 360-by-260 pixels to 20. For each face they have estimated a smile intensity index from behavioural data. The have fitted a linear regression model with the PCA scores as predictors and the smile intensity as the response variable. Their analysis is similar to the one you did in Homework 1.

All the data from their analysis are in the file that come with this exercise. Below is a description of the content of each file.

Filename	Content
image1, image2 and image3	360-by-260 matrices containing the brightness values for one image. The brightness values range from 0 to 1.
meanimage	A 360-by-260 matrix containing the brightness values for the mean image across all the images that the researchers used in their analysis. They subtracted this image from all the images before reducing the dimension of the images to 20 using PCA
PCA_Scores	A 3-by-20 matrix containing the PCA scores for the three images in the files image1-3
PCA_Components	A 93600-by-20 matrix containing the 20 PCA components (coefficients) as 20 column vectors. The first 360 elements of each PCA component corresponds to the first column in the corresponding 360-by-260 image. The next 360 elements correspond to the second column in the corresponding 360-by-260 image
RegressionParameters	The 20 parameters in the linear regression model
RegressionIntercept	The intercept in the linear regression model
SmileIndx	The smile intensity indices for each of the three images in the files image1-3

- The data set that comes with this exercise contains data from three selected images. What the model's predicted smile index of for each of the three faces? Explain how you calculated this. How do they compare to the true values?
- The model is not based on the actual images but on the PCA scores. Visualise the three faces reconstructed from the 20 principal components. Visualise the reconstructed faces and the corresponding actual images. Try to find an explanation for the discrepancies in predicted and true smile intensities from this visualisation.
- Homework 1 we created synthetic images with specific levels of smile, gender or some other attribute. In this problem we want to make synthetic face in a different way: take a specific face and change it so that it gets a smile index of 0.2 without changing other attributes of the face. Do this for each of the three faces that are included in the data that comes with this exam. Plot the images. You should still be able to identify the main features of the person from these reconstructed images but the facial expression should have changed. Explain your approach. Provide a table with the PCA scores each of the synthetic image.