Name:_____**StudentNr:**_____

Instructions

Welcome to the exam. Please read the following remarks:

- You have 3 hours to complete the exam (unless otherwise agreed for individual cases). So, until 20:00
- You can only start the exam once the lecturers have given the start signal.
- There are 4 questions, each with subquestions.
- For each question you can get a maximum of 10 points. Your exam grade is the average grade across all 4 questions.
- Please use only the designated area for answering open questions.
- Be *clear* and *concise* (i.e., do not make your answer too long). If you make an error, correct it clearly.
- Only write on the pages that belong to the specific question, not on other pages, otherwise we might overlook it.
- If you make an error, correct it clearly.
- You should provide your answers in English.
- It is not allowed to have any written materials on your table.
- It is not allowed to use any electronic equipment during the exam (e.g., no mobile phone, calculator, laptop).
- Write your name and student number on EACH PAGE.
- If you have any questions, raise your hand and we will see whether we can address them. This includes questions about English terms that you do not understand.

Once you are done

- Check that you have answered all questions.
- Check that each page has your name and student number on it.
- Walk up to the attendants who will collect your exam. Have your student ID ready.

Information about grades, resit, and exam inspection

- We will do our best to publish the grades within two weeks on Blackboard – hopefully earlier (due to travel, it's a bit slower than my usual standard, but we'll do our best)
- Information about the resit will follow.
- The exam contributes 40% of your final grade. In order to pass the exam you need a minimum unrounded grade of 4.50 on the exam.
- To pass the course you need to pass all components (see course manual) and have an average grade of at least 6.0
- An office hour will be arranged to inspect your exam.

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Question 1: Lectures by Chris Janssen (Processing & Final class)

1 A. (2 points)

In the 1st lecture we discussed 'Computational rationality: a converging paradigm for intelligence in brains, minds, and machines' by Gershman, Horvitz, and Tenenbaum. The article discusses why 'computational rationality' models are useful for AI, cognitive science, and neuroscience. One example is in medical decision making (be it by a human or an automated system).Explain (i) why a model-based computational rationality approach is useful for medical decision making, and (ii) how this approach contrasts with the classic homo economicus approach.

1 B. (2 points)

In the first class we also discussed the article 'Computational Rationality: Linking mechanism and behavior through bounded utility maximization' by Lewis, Howes, and Singh. In this paper they describe a model of the 'List Lexical Decision Task' in which participants need to classify whether a series of words contains a non-word. They classify this model at a specific level of "rationality". Answer these three questions:

(i) Which type of rationality is this? (i.e.: give the name)
(ii) What level is this? (i.e., pick: 1, 2, 3, or 4)
(iii) Why is this type of rationality, *and not other types*, appropriate for this model?

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1 C. (2 points)
In the second class we discussed the article 'The discovery of processing stages: extension of Sternberg's method' by Anderson, Zhang, Borst, and Walsh. One of the features of this model is the "linking assumption". *Explain briefly* what the linking assumption is.

1 D. (1 point)
In the 1st chapter of "Deep Learning" by Goodfellow, Bengio, & Courville, multiple reasons are given to be skeptic about deep learning models being able to model the full complexity of the human brain over the next 10-20 years. *Briefly* provide 1 reason.

1 E. (3 points)
For the second week's lecture you read the article by Anderson, Zhang, Borst, and Walsh (2016). They present multiple models of the associative recognition task (as discussed in class). Their eventual ACT-R model predicts the bumps in the EEG dataset. For this specific model, *explain* how you would categorize it using these categorization options that were discussed during the last lecture. Make sure to motivate each answer:
(i) is it top-down, bottom-up, or hybrid?
(ii) is it stand-alone or cumulative?
(iii) is it embodied?

(i)

(ii)

(iii)

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Question 2: Lectures by Ben Harvey (Machine learning)

2 A. (3 points)
In general terms, describe a way to quantify the performance of a supervised machine learning procedure.

2 B. (2 points) How do the goals of supervised and unsupervised machine learning differ?

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2 C. (3 points)

Some machine learning approaches include known properties of the modelled system in the model. Explain why this is desirable.

2 D. (2 points)

Explain why it is difficult for humans to understand how deep convolutional neural networks classify inputs, and what properties of these networks underlie this difficulty.

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Question 3: Lectures by Rick Nouwen and Frans Adriaans (Processing models in linguistics, Probabilistic models of language acquisition)

3 A. (2 points) (Rick Nouwen's lecture)

Say we have a very simple model of human sentence parsing where the parser builds all possible structures simultaneously and with each next word that is processed it keeps only those structures that can be extended with this new word. Explain in maximally 150 words how so-called garden-path sentences, like the following, are problematic for such models.
The horse raced past the barn fell.

3 B. (1 point) (Frans Adriaans' lecture)

As discussed in Frans Adriaans' lecture, computational language models are typically used for either engineering or cognitive modeling purposes. Explain in maximally 150 words how the purpose of the model has consequences for evaluation of the model's performance.

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3 C. (2 points) (Frans Adriaans' lecture)

Gaussian Mixture Models can be trained using the EM algorithm, which uses the training data to estimate three different parameters for each of a given number of categories. Name these three parameters, and provide a brief description of what they represent.

3 D. (5 points) (Frans Adriaans' lecture)

In class we discussed the article 'Linguistic Constraints on Statistical Word Segmentation: The Role of Consonants in Arabic and English' by Kastner and Adriaans (2018). In this paper, a Bayesian model is used to investigate word segmentation in two different languages: Arabic and English. Answer the following two questions:

(i) Explain why it is important to test cognitive models on multiple languages.

(ii) The article focuses on the role of consonants in Arabic and English. Explain in which of these two languages consonants are more important for word segmentation, and describe how computational modeling was used to come to this conclusion.

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Question 4: Integration across all lectures and labs

Question (10 points)

For the case study below you need to answer the following questions:

(i) With what general modeling type would you model this: a processing, machine learning, or probabilistic model?

(ii) Within that model type, what specific technique would you use? That is: what specific type of processing, machine learning, or bayesian model?

(iii) Why is this approach appropriate given the situation / case study at hand?

(iv) How would you approach the problem more specifically? Stated differently: how would you model this? What components are needed for such a model? What is the model structure? Note: of course you cannot describe the full code of the model, but provide the important steps in a *high level* way.

(v) What are important considerations and trade-offs for the modeling approach? For example, you can consider aspects such as parameter choice, structure of the model, how much learning the model does, what type of human data you need, fitting to human data, predicting new situations and generalization, validation, associated costs (e.g., computation time, memory). Focus on the important considerations and trade-offs for your model type.

All modeling types (processing, machine learning, probabilistic) could theoretically be applied to this case study, and none of these model types is "wrong" or "inappropriate" per se. Therefore, your choice of model will not give you points. Instead, the amount of points that you can earn on this question is determined by you demonstrating to us that you truly understood this technique. That is: you have a clear and correct motivation for each of the questions, especially questions iii to v. Comit to a specific approach and defend this position.

Case study:

A researcher wants to develop a human like game opponent, based on an underlying cognitive model for a traditional board or card game. The core idea is that the model/opponent acts in a human way. That is, it should not be a super computer that beats every human player. Instead, the model should also occasionally make a mistake or error, and should also occasionally loose, just like humans do.

For a game of your choosing, answer the above questions on how to model this game opponent. You can assume that the researcher has data of previous human games available to inform the model design. If a specific type of data is needed, make sure to mention this.

You are free to choose whichever game you want, but here are some suggestions out of which you can pick one (but feel free to choose another one). Indicate clearly in your answer about which game you are talking.

- *Tic-Tac-Toe (Dutch: boter-kaas-eieren)*
- *Set!*
- *Memory*
- *Quartets (card game. In Dutch "kwartetten")*
- *Scrabble*
- *Rummikub*

Answer this question on the designated pages

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Page for answering question 4 (do not use for other questions)

Name:_____StudentNr:_____

Extra page for answering question 4 (do not use for other questions)