CCN Exam Revision

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Structure of the exam

INSTRUCTIONS TO CANDIDATES

1. Note that ALL QUESTIONS ARE COMPULSORY.
2. DIFFERENT QUESTIONS MAY HAVE DIFFERENT NUMBERS OF TOTAL MARKS. Take note of this in allocating time to questions.
3. This is a NOTES NOT PERMITTED, CALCULATORS NOT PERMITTED examination.

   Notes and other written or printed material MAY NOT BE CONSULTED during the examination.

   CALCULATORS MAY NOT BE USED IN THIS EXAMINATION.

Structure of the exam

3 questions worth ~16 points, each covering one of the 4 following topics

- **Neural networks**
- **Drift Diffusion Models**
- **Reinforcement learning models**
- **Bayesian models**

Each question has typically 4 sub-questions, worth typically around 4 points (so allow about 10 minutes for each sub-question and about 40 minutes per question).

1) Neural Networks : checklist

a) **Hopfield Nets:**

- Could you explain how units are updated?
- Could you explain how memories are stored and what they correspond to?
- Could you explain how Hopfield nets have been used to model schizophrenia?

b) **Ring model:**

- Could you explain what the ring model was developed for?
- Could you explain how units are connected and updated?
- Can you explain what insight the ring model gives about the computation of orientation in V1, as well as working memory in higher cortical areas?

1) Neural Networks : checklist

c) Detailed model of Working Memory

- Could you give the equation for the integrate-and-fire neuron and explain each component?
- Could you explain why extending the ring model to spiking neurons wasn’t straightforward?
- Can you explain what key ingredient is needed in such network to account for working memory/ delay activity?
- Could you discuss when detailed models are better than simpler models?

2) DDM : checklist

- Can you recover the main equation?
- Can you explain how the model works?
- Do you understand what types of tasks are well suited to being fitted with DDM?
- Could you give one example of how the DDM could be used in the context of collecting and fitting behavioural data for understanding mental disorders?

3) Reinforcement learning Models: checklist

- Can you recover the Rescorla-Wagner learning rule (or Q-learning equivalent, i.e. just one step associations)?
- Can you explain how the model works?
- Could you add a new term to this equation that would test for a variant of the learning rule, e.g. a memory term, or sensitivity for reward etc..
- What tasks could be modelled with a RL model?
- Could you give an example of how Rescorla-Wagner have been/ could be used in the context of collecting and fitting behavioural data for understanding mental disorders, e.g. depression and addiction?

4) Bayesian models: checklist

- Can you give Bayes rule?
- Do you know what the likelihood ratio test is?
- Can you give the Bayesian prediction for integration of 2 cues in multi sensory integration (assuming the likelihoods are Gaussian).
- Similarly, do you understand how the impact of the prior vs likelihood depends on their precision/width?
- What tasks could be modelled with a Bayesian model?
- Could you give an example of how Bayesian models have been/could be used in the context of collecting and fitting behavioural data for understanding mental disorders, e.g. testing Bayesian theories of autism and schizophrenia?

4) Other

- Could you discuss what steps one should follow when using computational models to fit behavioural data?

- What are the goals of computational psychiatry?
- What are the challenges or limitations?

Do the labs

- The labs and the assignment explore each theme/model in more detail.
- Some of the questions will be very close to what they covered.
- You could be asked to write python code or pseudo-code (your choice) to implement (part of) a simple model (as a subquestion).

Example from last year

3. **Reinforcement-learning models.**
We consider a study using a probabilistic reversal learning task, where participants have to choose between two coloured rectangles (A or B) on each of 80 trials in order to maximize their reward. One of the stimuli is followed by a symbol representing a reward (£1) in 80% of the trials (and followed by nothing in the remaining trials), while the alternative choice leads to no reward on 80% of the trials and a reward (£1)on 20% of the trials. Unbeknownst to the participants, these contingencies reverse after 40 trials so that participants have to update their learning dynamically. We assume the authors of the study decide to fit the data with a model of the form:

$$V_i^{t+1} = \gamma V_i^t + \epsilon(r^t - V_i^t) \quad (1)$$

$$p_t(chooseA|V_A^t, V_B^t) = \frac{\exp(\beta V_A^t)}{\exp(\beta V_A^t) + \exp(\beta V_B^t)} \quad (2)$$

(a) Explain in words what all the terms in these equations mean i.e. how the variables are defined, what they represent, and how the model works. *[3 marks]*

(b) You are told that positive and negative prediction errors should be considered separately as they might be implemented differently in the brain and modulate learning differently. How can you modify the model to do that? Give the new equation and explain the terms in this new equation. *[3 marks]*

QUESTION CONTINUES ON NEXT PAGE

(c) Suppose the authors of this study want to run this experiment on two groups of participants, one with major depression (MDD) and the other without, fitting these two models to participants' responses to try to identify differences between the groups. What are the steps they need to take, before and after data collection, to make sure that, from a modeling perspective, their analysis will yield meaningful insights and conform to current scientific standards? *[7 marks]*

(d) Suppose that the authors find that participants with MDD learn more slowly from positive prediction errors, and quicker from negative prediction errors, than participants without MDD. If this result generalizes to more complex learning in everyday life, what would the implications of this finding be for our understanding of MDD ? *[4 marks]*

Q&A