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 subquestion 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).

An example (fake) exam question

1. **Reinforcement learning models**

The Signal Detection Task (Pizzagalli et al., 2005) is a probabilistic reward learning paradigm used to study reward processing deficits in depression. In this task, participants repeatedly categorize two stimuli (e.g., short vs. long lines). Importantly, the task is difficult, and one response (e.g. either short or long) is rewarded more frequently than the other.

(a) Why is studying reward processing pertinent to the study of depression? What is the expected effect of the asymmetry in the reward scheme in this task and how could this be measured experimentally? [*4 marks*]

(b) The researchers used the Rescorla-Wagner learning rule to model their data. Write down this learning rule and briefly explain its components. [*4 marks*]

(c) Explain how reward sensitivity can be incorporated into this learning rule. How would changes in reward sensitivity affect learning in the Signal Detection Task? [*4 marks*]

(d) Supposed the researchers have fit this model to the behaviour of 2 groups of participants, one with depression and one without depression. They find that the parameter for reward sensitivity is lower in the group with depression. Can they be confident that their hypothesis is validated and that depressed individuals are characterised by lower reward sensitivity in this task? If not, explain what additional steps they need to take. [*4 marks*]

Q&A