Version ML/2

EGT2
ENGINEERING TRIPOS PART IIA

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Monday 27 April 2015 14.00 to 15.30

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**Module 3G3**

**INTRODUCTION TO NEUROSCIENCE**

*Answer not more than **three** questions.*

*All questions carry the same number of marks.*

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

*Write your candidate number **not** your name on the cover sheet.*

**STATIONERY REQUIREMENTS**
Single-sided script paper

**SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM**
CUED approved calculator allowed
Engineering Data Book

## 10 minutes reading time is allowed for this paper.

## You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

1 (a) This question is about the Hodgkin-Huxley model for action potential generation.

(i) State and explain:

A. the differential equation that Hodgkin and Huxley used to describe the dynamics of the membrane potential; [10%]

B. the equation for the sodium current in terms of the gating variables and the membrane potential; [10%]

C. the differential equation for one of the gating variables. [10%]

(ii) The membrane potential of a neuron in voltage-clamp mode is very slowly increased from $-100\,\text{mV}$ to $20\,\text{mV}$. Sketch and describe how:

•the two gating variables for sodium; and

•the sodium current

change as a function of the membrane potential. [15%]

(iii) Explain which of the gating variables is responsible for the positive feedback that triggers the action potential. [5%]

(b) This question is about the drift-diffusion model for perceptual decision making.

(i) Name the parameters of the drift-diffusion model for perceptual decision making and explain their role. [15%]

(ii) Explain the speed-accuracy trade-off within this model. [15%]

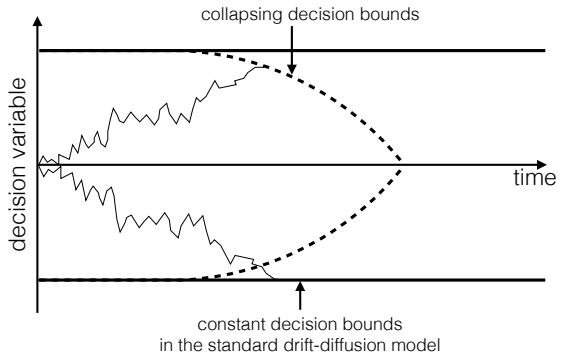


Fig. 1



(cont.

(iii) In many decision making experiments, subjects are put under time pressure by requiring a response within a given time interval. To incorporate time pressure into the drift-diffusion model, a common variation of the model lets the decision bounds gradually collapse to zero over time (see Fig. 1).

- Sketch and describe the shape of the reaction time distribution for the standard drift-diffusion model with constant decision bounds.
- Sketch and explain how the reaction time distribution is altered by collapsing bounds.
- Explain with reasons whether you would expect the fraction of correct responses to increase or decrease as the decision bound approaches zero.

[20%]

2 (a) Write short notes on the following:

(i) functional magnetic resonance imaging and its strengths and weaknesses; [15%]

(ii) the Eriksen flanker task and what it teaches us about spatial attention; [15%]

(iii) the assumptions of signal detection theory (provide a graphical illustration with your answer). [15%]

(b) A point sound source is located at an azimuthal angle $\theta$ and a distance $r$ from a listener as shown in Fig. 2. The head width of the listener is $l = 0.2\,\mathrm{m}$ which can be assumed to be much smaller than the distance to the point source. The speed of sound is $c = 340\,\mathrm{m\,s^{-1}}$.

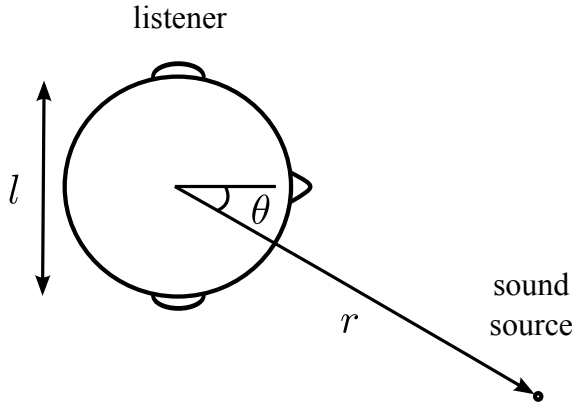


Fig. 2

(i) The point source emits a click. Sketch how the resulting interaural time difference (ITD, using left ear minus right ear convention), varies as a function of $\theta$ over the range $-\pi \leq \theta < \pi$. Label the values of the maximum and minimum ITDs and the azimuthal angles at which they occur. [15%]

(ii) Listeners sometimes experience a so-called front-back confusion where they perceive a source that is located in front of them as being located behind them and vice versa. Explain the origin of this phenomenon using your sketch. [10%]

(iii) The point source now emits a 3kHz sinusoid. Disregarding the front-back confusion, can the source be reliably localised using ITDs in this case? Explain your reasoning by considering the signals arriving at the two ears. [15%]

(iv) Describe the Jeffress model for the neural processing of ITDs in the medial superior olive. [15%]

3 (a) In a voltage-clamp experiment, a neuron is stimulated by local application of glutamate, and the postsynaptic current is measured. Sketch and describe in words the membrane current as a function of time under the following eight conditions, and explain with reasons why the postsynaptic current differs across conditions:

| condition | holding voltage | APV is applied together with glutamate |
|---|---|---|
| 1. | −100 mV | no |
| 2. | −50 mV | no |
| 3. | 0 mV | no |
| 4. | +25 mV | no |
| 5. | −100 mV | yes |
| 6. | −50 mV | yes |
| 7. | 0 mV | yes |
| 8. | +25 mV | yes |

Ensure that you define units on the axes of your plots. [40%]

(b) Describe the main differences between massed training and spaced training for habituating the gill-withdrawal reflex in *Aplysia* in terms of:

- the stimulation pattern applied;
- their effects on habituation;
- their mechanisms.

[30%]

(c) In an *in vitro* experiment about LTP, extracellular electrodes are used both for stimulation and recording. Sketch the extracellular potential signals that can be recorded following a stimulation before and after the induction of LTP, when the recording electrode is in the same layer where cell bodies of the postsynaptic cells are located. Describe in words the main components of the recorded signals, their electrophysiological sources, and the main differences between the "before" and "after" signals. [30%]

4 (a) You are to design an experiment in which you can use a neurotransmitter antagonist to attempt to distinguish between the contributions of hippocampal LTP to at least three different navigational strategies during spatial navigation. Include the following details, and explain your choices in all cases:

(i) What receptor would you block with your antagonist? At what point(s) during the course of the experiment would you apply your antagonist? [10%]

(ii) What kind of behavioural task would you use to assess the performance of animals, and how would you measure their performance? [20%]

(iii) What results would you expect from your experiment? [10%]

(iv) If you had the opportunity to do *in vivo* electrophysiological recordings, how would you do them to give further support to your results? [20%]

(b) In a classical conditioning experiment, three different conditioned stimuli (CS), $CS_1$ (a light), $CS_2$ (a tone), and $CS_3$ (a click), are used to signal the same US (unconditioned stimulus, e.g. the delivery of food). Before training, none of the CSs evoked a response. Describe how strong a response (if any) you would expect for each of the CSs presented in separation after the following training protocols:

- phase 1: $CS_1 + CS_2 + US$; phase 2: $CS_3 + CS_1$
- phase 1: $CS_1 + CS_2 + US$; phase 2: $(CS_3,CS_1) + US$
- phase 1: $CS_1 + CS_2 + US$; phase 2: $(CS_3 ,CS_1,CS_2) + US$

where e.g. $CS_1+CS_2$ stands for sequential presentation of stimuli, and $(CS_1,CS_2)$ means simultaneous presentation of stimuli. [40%]

**END OF PAPER**