Version HS/2

EGT3
ENGINEERING TRIPOS PART IIA

Tuesday, 29th April 2014 14.00-15.30

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

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

1 (a) Write short notes:

(i) on the advantages and disadvantages of local and intensity coding schemes for location; [15%]

(ii) on behavioural evidence for multisensory integration; [15%]

(iii) comparing the attentional pop-out effect and serial visual search. [15%]

(b) Explain the structure and function of the middle ear, illustrating your answer with a diagram. What properties of the middle ear might explain why people find that their own recorded voice sounds strange? [25%]

(c) In comparison to normal hearing, electrical hearing using cochlear implants is limited in terms of the range of frequencies that can be heard, the frequency resolution, and pitch discrimination. Using your knowledge of cochlear implants, explain the nature and origin of these limitations. [30%]

2 (a) This question is about perceptual decision making.

(i) Describe the drift-diffusion model for perceptual decision making. [20%]

(ii) Describe two properties of neuronal responses in the lateral intraparietal area of macaque monkeys that support their interpretation as neural correlates of the decision variable in the drift-diffusion model. [20%]

(b) This question is about the neuronal resting potential and action potential generation.

(i) Explain how the permeability of the cell membrane for sodium and potassium ions affects A) the reversal potentials for these ions and B) the resting potential of the cell. [20%]

(ii) Hyperkalemia is a serious and potentially lethal medical condition in which the extracellular concentration of potassium ions is pathologically increased. Explain what happens to the neuronal resting potential in response to rising extracellular potassium concentration. [15%]

(iii) During the development of hyperkalemia, the extracellular potassium concentration rises relatively slowly (compared to neuronal time scales) over a course of minutes or hours. Explain the effects such a slow rise in extracellular

potassium concentration has on voltage-gated sodium and potassium channels and how it affects the generation of action potentials. [25%]

3 This question is about the properties of synaptic transmission in four different synapse types:

type 1 – the presynaptic cell is excitatory and the postsynaptic cell is excitatory;
type 2 – the presynaptic cell is excitatory and the postsynaptic cell is inhibitory;
type 3 – the presynaptic cell is inhibitory and the postsynaptic cell is excitatory;
type 4 – the presynaptic cell is inhibitory and the postsynaptic cell is inhibitory.

(a) Describe the sequence of cellular-molecular events during synaptic transmission for each of the above synapse types. For each type, include in your answer the name of a relevant neurotransmitter. [40%]

(b) In which of the above synapse types can AP5 have an affect on synaptic transmission? For those in which it can, explain under what conditions and how it alters A) the sequence of cellular-molecular events described in (a) and B) the shape of the postsynaptic response. [40%]

(c) For each of the above synapse types, give an example in the gill withdrawal reflex pathway of the Aplysia, or state if there are no examples for it in this pathway. For each example synapse you provide, describe how its strength changes in habituation. [20%]

4 (a) Describe how the Morris water maze is used to study spatial memory. In your answer include a description of the basic experimental setup, the behavioural measures that are used to quantify learning, and also the procedures by which one can ensure that behaviour is not based on navigational strategies that are independent of spatial memory. [30%]

(b) This question is about reward learning in stochastic, non-stationary environments, i.e., environments in which rewards are stochastic and their probabilities may change over time. Each experiment described below uses a novel conditioned stimulus (CS). All experiments start with 10 baseline trials, in which no CS or reward (US) is given, followed by 100 conditioning trials in all of which the CS is given. The experiments differ in the way the US is delivered in the 100 conditioning trials.

Experiment 1: US is delivered in all of the 100 conditioning trials.
Experiment 2: US is delivered in a random 50% of the 100 conditioning trials.
Experiment 3: US is delivered in all of trials 11-35 and 61-85, but not in trials 36-60 and 86-110.
Experiment 4: US is delivered in a random 75% of trials 11-60, and a random 25% of trials 61-110.

(i) In each experiment, plot the response and the *squared* prediction error as computed by the Rescorla-Wagner rule for two cases: when the learning speed is high ($\sim$0.9), and when the learning speed is low ($\sim$0.05). (Note that it is the squared, not the signed prediction error that needs to be plotted.) [40%]

(ii) Describe the role of the *squared* prediction error in the Rescorla-Wagner learning theory. [10%]

(iii) Different environments can vary in their stochasticity (i.e., how stochastically rewards are given), and their non-stationarity (i.e., how often reward probabilities change). Explain with reasons how these two factors influence whether a high or a low learning speed is more advantageous. [20%]

END OF PAPER