Tfy-99.3730 Information Processing in the Brain **Exam, 19.05.2011**

> Write your name, student number, signature and "Tfy-99.3730" on each sheet of paper. You need to return all papers, including the questions and your drafts and notes. Mark the draft papers clearly.
>
> Note that brief really means brief. At most one page should be enough for answering each of the four questions.
>
> For questions 3 and 4, answer **either** A **or** B question.

1. (6 pts)

Explain briefly the following concepts and their relation to the brain:

- Temporal credit assignment problem
- Go - no-go pathways in basal ganglia
- Attractor network
- Conjunctive coding
- Slow feature analysis
- Spike-timing-dependent plasticity

2. (6 pts)

Describe briefly the function and learning principles of the following brain areas:

- Cerebellum
- Basal ganglia
- Cerebral cortex

3A. (6 pts)

Assume an autoassociative memory with 12 000 binary neurons. In a memory pattern, each neuron is active with 2 % probability (on average, there are 240 active neurons in one pattern).

3A.1 What is the average overlap of two patterns (expected number and percentage of shared active neurons)?

3A.2 What is the probability that two random patterns share at least 24 active neurons (at least 10 % overlap)?

Hint: The binomial distribution can be approximated by the Poisson distribution

$$P(k) = \frac{\lambda^k e^{-\lambda}}{k!},$$

which gives the probability of k hits when the expected number of hits is λ.

3A.3 How is this question related to the brain?

3B. (6 pts)

Dentate gyrus produces random sparse neural activation patterns. What are they used for and why are they random and sparse?

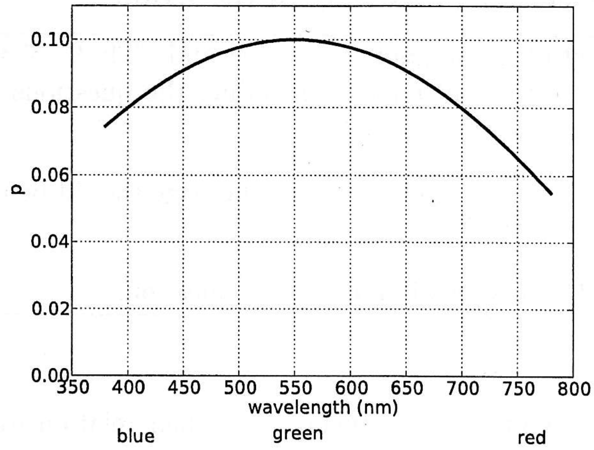

Figure 1: For 4A.2: the probability density function of different wavelengths in the test animal's sensory inputs during learning.

4A. (6 pts)

4A.1 Let us consider a simplified model of a neuron that only takes into account spiking frequencies and neglects all other temporal information in spikes. We have a neuron that gets a real-valued input x, and then generates a real-valued activation $y = f(x)$. The inputs follow a probability distribution $p_x(x)$ and the activation function $f(x)$ is monotonically increasing and between 0 and 1. Derive the activation function that maximizes the entropy of the neuron?

4A.2 Suppose you are testing a hypothesis which says that an animal's ability to discriminate different colors depends on a particular neuron somewhere in the brain. This neuron adapts its activation function to maximize the neuron's entropy. The input to the neuron represents the wavelength of the seen color. The probability distribution of different colors in the sensory inputs of the animal is plotted in Figure 1. You have done an experiment with the animal showing that it can discriminate a color from green color 550 nm if the wavelength difference is at least 5 nm. Next you are going to test how big the wavelength difference has to be to discriminate a color from 700 nm color. Which outcome does the hypothesis predict?

4B. (6 pts)

For the following two information coding mechanisms, descibe 1) what they mean, 2) where in the brain they are used and 3) how (if at all) they affect learning, generalization, storage capacity and sensitivity to noise.

- whitening (also known as sphering)
- sparse coding