Tfy-99.3730 Information Processing in the Brain **Exam, 27.08.2009**

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
Hippocampus

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?

4A. (6 pts)

4A.1 What do we know about n if the following equations hold?

$$n \equiv 2 \mod 4 \qquad n \equiv 1 \mod 5 \qquad n \equiv 4 \mod 6$$

4A.2 We have gathered a dataset of vectors $\mathbf{x}(t)$ and $\mathbf{y}(t)$. They satisfy $E\{\mathbf{x}\} = E\{\mathbf{y}\} = \mathbf{0}$ and the following:

$$E\{\mathbf{x}\mathbf{x}^T\} = \begin{bmatrix} 4 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad E\{\mathbf{y}\mathbf{y}^T\} = \frac{1}{2}\begin{bmatrix} 5 & 3 \\ 3 & 5 \end{bmatrix} \qquad E\{\mathbf{x}\mathbf{y}^T\} = \frac{1}{2}\begin{bmatrix} 0 & 0 \\ 1 & -1 \\ 1 & 1 \end{bmatrix}$$

Find the projection vectors $\mathbf{w}_x$ and $\mathbf{w}_y$ such that the signals $z_x(t) = \mathbf{w}_x^T\mathbf{x}(t)$ and $z_y(t) = \mathbf{w}_y^T\mathbf{y}(t)$ are maximally correlated and have unit variances: $E\{z_x^2\} = E\{z_y^2\} = 1$.

4A.3 How are problems 4A.1 and 4A.2 related to the brain?

4B. (6 pts)

Describe the cortical column: anatomy (including external connections), physiology and other relevant features. Explain how these are relevant for higher-level phenomena such as perception, attention, learning and decision making.