Neurosciences – Exam 2014-2015

Research Master Human Movement Sciences

- **Please select**
  - **3 of the 4 questions in part I (i.e. I.1, I.2, …, I.4) and**
  - **3 of the 4 questions in part II (i.e. II.1, II.2, …, II.4).**

  Answer only these 2×3 questions!
  If you provide more answers to a part we will only look at the first 3 answers each.
  Maximum score is 2×30=60 points!

- **Please provide your answers for the parts I, II on separate sheets.**

- **Please fill in your name and student number on each answer sheet.**

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Part I

Question I.1

Ongoing encephalographic activity is often characterized by different rhythms, i.e. oscillations in distinct frequency bands.

a) Name four bands including their frequency range and primary location, and list briefly what is considered their function.
Hint: put your answer in a table.

(*4 points*)

theta	*~ 4-8 Hz*	*(pref-)frontal / parietal*	*attention / awareness*
alpha	*~ 8-14 Hz*	*occipital lobe* *motor cortex (mu rhythm)*	*visual processing* *motor control*
beta	*~ 20-30 Hz*	*primary motor cortex*	*motor control*
gamma	*~ 40-80 Hz*	*(pref-)frontal / parietal*	*attention / cognition*

b) The frequency of oscillations may relate to the spatial extent over which the activity can be observed. Explain <u>why</u> there could indeed be a relation between the spatial extent of these neural populations and their firing frequencies.

(*3 points*)

Oscillations may stem from neuronal feedback loops; the longer the distance between the units, the longer the delay and, hence, the lower the frequency

c) Give two methods to quantify the inter-relationship between two (or more) oscillatory populations. Explain briefly what is being quantified (i.e. what is the outcome variable) and how it is determined (i.e. how is it computed – here you may also provide the mathematical form).

(*3 points*)

1. *Amplitude-amplitude correlations, i.e. determine the amplitude (square root of power) of the M/EEG at certain locations and correlate them using, e.g., Pearson's correlation*
2. *Phase synchronization, i.e. determine the phase (e.g. Hilbert phase) of M/EEEG at certain locations in a certain frequency band and estimate the divergence of their difference.*

Question I.2

MEG and EEG are standard techniques to assess cortical activity. When looking at the peripheral nervous system another modality, EMG, is often applied.

a) Explain briefly what is been assessed using EMG (i.e. what type of activity is measured?).

(*3 points*)

Using needle EMG, possible individual motor unit action potentials. With surface EMG, the sum of action potentials over one (or more) motounit-pools.

b) If you are interested in cortico-muscular interaction you may combine EEG with EMG and estimate coherence. How does this cortico-muscular coherence alter when a subject changes from a static isometric force (precision pinch-grip) to a dynamic isometric force production?

(*3 points*)

During precision grip, the cortico-muscular coherence is maximal and it drops significantly in the dynamics phase of force production.

c) The same coherence measure may be used for estimating the synchrony between different areas in the cortex. What is the main confounding factor when doing so?

(*2 points*)

Volume conduction can yield spurious estimates of synchrony; alternatively, the mere signal-to-noise ratio can also change synchrony.

d) In the cortex the spectral power of encephalographic activity is considered a measure for local synchrony.
How does the power change in the case outlined in sub-question I.2.b. That is, a subject produces a static precision pinch-grip and changes to a dynamic force production (see above).

The change of power agrees with I.2.b when looking at the beta frequency band: during the static phase the power is strong and drop as soon as (or slightly prior to) entering the dynamic phase; keyword "event-related desynchronization (ERD)"

And, how does the power change if the subject returns to the precision pinch-grip (hint: movement termination)?

(*2 points*)

When returning to the static phase the beta power returns to the large value and even displays a slight overshoot (beta rebound); keyword "event-related synchronization (ERD)", this is seminal for what is often considered movement termination.

Question I.3
M/EEG recordings often employ an event-related design.

a) Explain briefly the quantitative benefit of the event-related design over, e.g., assessing ongoing activity?

(*3 points*)

By averaging over event the activity that is not task-related cancels out.

b) Provide an example of an experiment using such a design for motor performance and interpret its outcome. Limit your answer to a maximum of a fifty words.

(*4 points*)

Tapping to the beat; events are given via the onset of stimulation tones. Suppose conditions differ in beat, then event-related amplitudes over contralateral primary motor cortex will drop with increasing tempo, which may let you believe that tempo (or) beat is controlled via amplitude (AD: which is btw a false interpretation).

c) Transcranial magnetic stimulation (TMS) can be used to elicit so-called motor-evoked potentials (MEP) in the EMG. What kind of EMG-potential do you expect when stimulating …
(i) once with a very weak magnetic field? *No response, since stimulation is below threshold.*
(ii) once with a reasonably strong field? *A certain MEP with a fixed delay of TMS pulse.*
(iii) with a reasonably strong field at a high repetition rate? *Same as (ii) but now at the rate of stimulation. If the rate is to high, however, no response as the stimulated neurons stay in the silent period.*

Motivate your answers (total maximum is fifty words).

(*3 points*)

Question I.4
Neural mass models are used to describe the activity of fairly large neural populations. One example is the Wilson-Cowan model discussed in class, which covers the mean firing rate of excitatory and inhibitory population. The Freeman model, by contrast, describes the average dynamics of membrane potentials. For a single population this model reads:

$$\frac{d^2V}{dt^2} + (\alpha + \beta)\frac{dV}{dt} + \alpha\beta V = \alpha\beta\, F\{S\left[V_{\text{ext}}\right]\}$$

where V is the mean membrane potential, V_{ext} and external potential (caused by an injection current) and α and β are just some (positive!) parameters. The function S is a sigmoid (similar to the one in the Wilson-Cowan model) and F is a transfer function mimicking the total mean effect of all the synapses.

a) Describe how the response of V to an input-spike may look like.
The answer can be given in words, or as a graphical sketch, or as an equation.

(*3 points*)

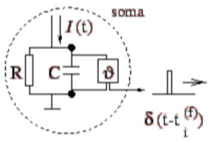
2nd order response of an overdamped system: slow rise followed by an exponential decay.

b) To obtain synchronized oscillatory activity two populations need to be coupled. How is the qualitative nature of the coupling?

(*2 points*)

E.g., from A -> B excitatory and from B -> A inhibitory.

c) The Freeman model can be deduced from the LIF-model whose electric circuit and its mathematical description are given below.



$$\underbrace{C\frac{dV}{dt}}_{(i)} + \underbrace{g_L\left(V - V_L\right)}_{(ii)} = \underbrace{I}_{(iii)} \quad \text{and if } V \geq \theta, \text{ then } V = V_{\text{reset}}$$

Explain how the ingredients (i), (ii), and (iii) of the LIF-model may transfer to the Freeman model above.

(*3 points*)

They don't as transferring a population of LIF neurons to the Freeman model requires the inclusion of the synapse dynamics (i.e. a second 1st order response). However, you may argue that $\alpha\beta$ must equal g_l/C

d) The LIF-model is a 1st order differential equation whereas the Freeman model is 2nd order. Give a neuronal mechanism (or part of a neuronal network) that may cause the increase in order when looking at these neural masses.

(*2 points*)

The synapse(s).

Part II

Question II.1

a) For a spiking neuron which of the conductances is the most important for the neuron's behavior …

(i) … when the neuron is at the resting potential? *Potassium (most open)*

(ii) … during the maximum depolarization of a spike discharge? *Sodium (most open)*

(iii)… during the repolarizing phase of a spike discharge? *Potassium (opens)*

(iv)… during the refractory period? *Sodium (h-gates are closed)*

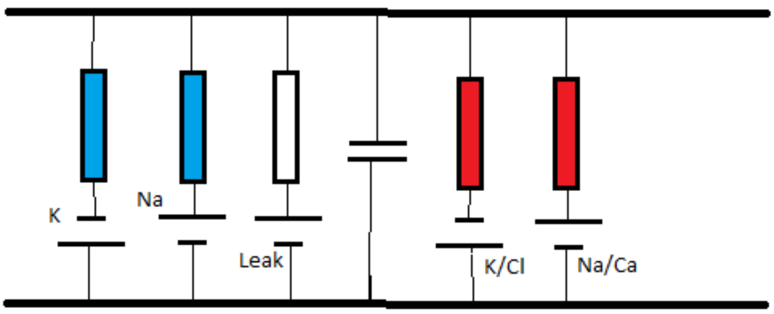
(v) … during an IPSP? *Potassium/Chloride (inhibition)*

(vi) … during an EPSP? *Sodium/Calcium (excitation/plasticity)*

(*6 points*)

b) Draw an equivalent electrical circuit diagram incorporating all the conductances needed to answer the question. Label the elements of this diagram and indicate which of these channels are voltage dependent, and which are switchable

(*4 points*)



Blue: voltage sensitive
Red: switchable (synapses)

Question II.2

a) Which equation describes the electrical volume currents in a conducting medium that result from the impressed current due to neural activation?
Give either the name of the equation or its explicit mathematical form.

(*2 points*)

Laplace's equation (or the microscopic Ohm's equation when taking the divergence of it on both sides).

In your own words: What does this equation mean?

(*2 points*)

The second spatial derivative of the potential vanishes everywhere except at the sources or sinks of the impressed current.

b) If you would measure the scalp EEG while the subject's head is immersed in salt water what effect would that have on the volume currents at the scalp surface, and would the resultant EEG amplitude be larger or smaller than when recording outside the salt water?

(*6 points*)

Salt water will cause a short between the electrode leads; causing a decrease of EEG amplitude

Immersion in saltwater also means that current lines may leave and enter the head, making it much more plausible for the electric current to go through the EEG electrodes, making the EEG amplitude larger.
Which of these two effects is the largest can only be determined by solving the forward Laplace equation in these two conditions

Question II.3

a) When the brain is described as a dynamic network of dynamic networks, which steps need to be taken to quantify the spatial, topological, and statistical properties of the brain?

(*4 points*)

Record epochs, reconstruct sources, determine the functional connectivity, describe the topology.

b) How does the construction of the networks differ when using fMRI, structural MRI, or MEG data?
Hint: Put recording modalities and construction steps and analyses in a single table.

(*6 points*)

modality	*record*	*reconstruct*	*connectivity*	*Topology*
MEG	*Ongoing fast spatially limited*	*Beamforming To AAL*	*Functional/Effective "correlations" in different frequency bands*	*Graphs*
MRI	*No time info Good resolution*	*Segmentate/ Voxelwise*	*Cortical thickness corr over subjects| DTI|cluster voxelwise*	*Graphs*
fMRI	*Ongoing Slow Few time samples Many voxels*	*Segmentate*	*Linear correlations (remove| correct negative correlations)*	*Graphs*

Question II.4

The gradient systems in an MRI scanner can be used for different goals.

a) Describe how these systems are used to code the MR signal for the position in space of the source of the MR signal.

(*5 points*)

Slice selection during nutation|flip; frequency selection during echo; phase selection between flip and echo.

b) Describe another use of the gradient systems, and an application of this use.

(*5 points*)

By alternatingly presenting positive and negative gradients between flip and echo the diffusion of spin carrying particles in the direction of the gradient can be determined. This is used in fMRI.