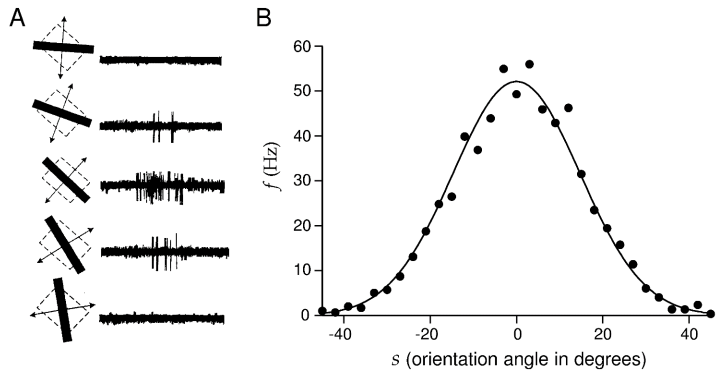
Neuroengineering 2023-2024

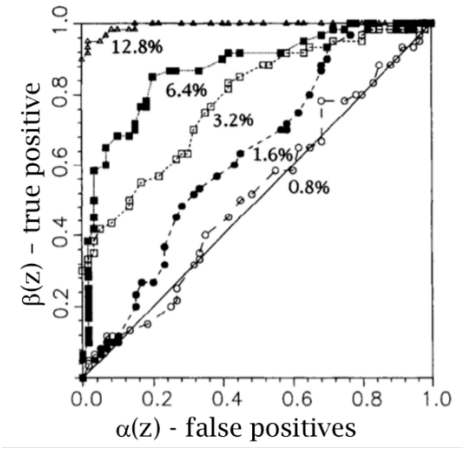
**Exam 10 September 2024 – Part I**

**Solutions**

# Section A

| # | Question | Ans. | Explanation |
|---|---|---|---|
| 1 | The voltage-gated $K^+$ channel inactivation state is responsible for the absolute refractory period. | F | *The voltage-gated $Na^+$ inactivation state is responsible for the absolute refractory period. $K^+$ voltage-gated channel does not go through any inactivation state.* |
| 2 | The firing rate influences the amplitude of the resulting action potential in the post-synaptic cell. | F | *It can affect the temporal summation and therefore the amplitude of the post-synaptic potentials, not of the action potential.* |
| 3 | Temporal and spatial summation can occur simultaneously. | T | |
| 4 | The brain operates at the temporal scale of milliseconds. | T | |
| 5 | The frontal lobe houses the primary visual function. | F | *The primary visual cortex is located in the occipital lobe.* |
| 6 | The synchronicity of the neural activity affects the amplitude of EEG signals. | T | |
| 7 | The neurons' spatial orientation affects the amplitude of EEG signals | T | |
| 8 | The short-term synaptic plasticity involves a structural change in the post-synaptic membrane. | F | *The short-term synaptic plasticity only involves functional changes (not structural ones)* |
| 9 | Scalp EEG is mainly produced by deep (subcortical) regions. | F | *It is mainly produced by cortical regions.* |
| 10 | The part of the pyramidal neuron that acts as a current dipole is the axon | F | *It's the dendritic tree.* |

| # | Question | Ans. | Explanation |
|---|---|---|---|
| 11 | We need to measure the amplitude and duration of an action potential each time it occurs to understand the cell behavior. | F | *The amplitude and duration are the same for all APs.* |
| 12 | The neuronal resting membrane potential is given by the sum of diffusional forces, electrical forces, and ion pumps activity | T | |
| 13 | Given the following tuning curve, reporting the firing rate of a neuron of the primary visual cortex (B) in response to the orientation angle of a visual stimulus (A):<br>  <br><br>If the measured firing rate is 20 Hz, I can infer a univocal orientation angle that produced that response. | F | *There are two possible orientations that produce a 20 Hz firing rate (-20 and 20 degrees).* |
| 14 | In reference to the previous figure: from the curve I can conclude that there is a preferred stimulus orientation for which this neuron is designed to respond. | T | |
| 15 | In reference to the previous figure: there are stimulus orientation angles to which this neuron is “blind” (i.e., it doesn’t show any response). | T | |

| # | Question | Ans. | Explanation |
|---|---|---|---|
| 16 | Given the ROC curves in the figure, describing a threshold classification between two conditions (stimuli) at different levels of coherence of the stimulation:<br>  <br><br>The best curve is the one closer to the upper left corner. | T | |
| 17 | In reference to the previous figure: the Area Under the Curve (AUC) for each level of coherence is proportional to the discriminability of the two conditions. | T | |
| 18 | In reference to the previous figure: by considering only the true positives and false positives, and neglecting the true negatives and false negatives, we miss part of the results of the classification. | F | *True negatives and false negatives are related to false positives and true positives, respectively. Therefore, we are not neglecting any result of the classification.* |
| 19 | The difference between the Wiener's and Granger's definitions of causality in the statistical sense is that Granger indicated a modeling framework to be used to test causality. | T | |
| 20 | Given the Granger Index $G_{xy}$ between two time series *x* and *y*, a negative value of $G_{x\rightarrow y}$ means an inverse precedence between the two time series. | F | *A negative value of $G_{x\rightarrow y}$ means that the residual of the bivariate model is higher than in the simple model, which is probably due to an incorrect modeling.* |
| 21 | The Granger Test is more suitable than the Ordinary Coherence to obtain a spectral measure. | F | *GC is not a spectral measure. OC is.* |

| # | Question | Ans. | Explanation |
|---|---|---|---|
| 22 | In an undirected graph, I cannot compute the indegree and the outdegree. | T | *The concept of "in-degree" and "out-degree" is based on directionality.* |
| 23 | Regular networks have a smaller Local Efficiency than random networks | F | *Regular networks have a high Local Efficiency (higher than random ones).* |
| 24 | In a graph, the minimum Divisibility is equal to zero. | F | *According to the most used normalization, the minimum Divisibility is equal to 0.5. More generally, even with different choices of the term k, D can never be equal to zero.* |

# Section B

| # | Question | Ans. | Explanation |
|---|---|---|---|
| 1 | The proper (visual) alpha rhythm is modulated (synchronized, desynchronized) by opening and closing the eyes. This phenomenon is best observed on the frontal EEG channels. | F | Only the first half of the statement is true. The primary visual area is located in the occipital cortex, thus the occipital (and parietal) channels are most sensitive. |
| 2 | The alpha rhythm can be observed by filtering the spontaneous EEG signal using a narrowband filter, with cutoff frequencies at 14 and 30 Hz (approximately) | F | With these cutoff frequencies we would observe the beta rhythm |
| 3 | Evoked potential is synonymous of Event-Related Potentials | F | Event related potentials include evoke potentials, as well as EEG responses to motor or cognitive events. |
| 4 | Despite being more expensive, gold electrodes should be preferred to Ag/AgCl electrodes since they allow recording of extremely slow-changing EEG potentials. | F | Gold electrodes are polarizable, thus the opposite is true |
| 5 | The CMRR of a bipolar amplifier measures the ratio between the gain of their average with respect to the electrical ground and the gain of the potential difference between the input electrodes. | F | Numerator and denominator are swapped |
| 6 | The measurement of two monopolar EEG channels requires four electrodes – two collecting the potentials fed to the non-inverting input of the differential amplifier, one providing the reference potential and one providing the ground potential. | T | TRUE |
| 7 | If the electrodes' contact impedance is not much lower than the amplifier's input impedance, the amplitude of the measured potential is closer to zero than the actual value. | T | True. In fact, the series of the electrode impedance and input impedance act as a voltage divider. Only if the former is much lower than the latter, the voltage at the amplifier's input is approximately equal to the actual biological potential. |

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|---|---|---|---|
| 8 | EEG electrodes whose first letter of the label is “C” (e.g. “Cz”) are located on the central region of the head, i.e. the region between the left and the right hemisphere | F | The central region is above the central sulcus which divides the frontal and parietal lobes. The mesial region is above the interhemispheric scissure, and it is designated by a trailing “z” in EEG labels |
| 9 | The artifact generated by eye movements can reach amplitudes up to $5\mu V$ in the EEG recordings | F | EOG artifacts can be two orders of magnitude higher than that. |
| 10 | The heart activity is likely to contaminate an EEG recording if the reference electrode is not placed on the head. | T | TRUE |
| 11 | In ERP analysis, the EEG continuous recording must be segmented into epochs (trials) of fixed duration, each aligned to a repetition of the event | T | TRUE |
| 12 | A negative peak in a ERP recorded on a specific subject with a latency of $108ms$ may still be named N100, if it matches the physiological phenomenon of the nominal N100 component. | T | TRUE |
| 13 | In an ERP, the response to a stimulus has a reduced amplitude when the SOA is too short. | T | TRUE |
| 14 | Induced activity is often examined by analyzing the envelope of the EEG in a relevant frequency band, i.e. by rectifying or squaring the pass-band filtered trials before averaging them. | T | TRUE |
| 15 | The reconstruction of an analog signal from its sampled version is equivalent to the sum a set of $sinc(\cdot)$ functions, one for each sample. | T | TRUE |
| 16 | Aliasing occurs when an analog signal is sampled using a limited input range of the ADC. | F | Aliasing occurs when an analog signal is sampled outside the conditions set by the Shannon’s theorem. Clipping (saturation) occurs when the input range of the ADC is smaller than the amplitude of the input analog signal. |
| 17 | In an ADC, quantization introduces a noise whose amplitude is proportional to the width of the quantization interval ($V_{LSB}$): $\sigma_{quant} = \frac{1}{\sqrt{12}} \cdot V_{LSB}$ | T | TRUE |

| # | Question | Ans. | Explanation |
|---|---|---|---|
| 18 | $ARV_x = \sqrt{\frac{1}{N}\sum_i (x[i])^2}$, where the sum extends on the N samples of the signal x[i] | F | $ARV_X = \frac{1}{N}\sum_i \lvert x_i \rvert$, ARV being the acronym of Average Rectified Value |
| 19 | It is more likely that samples of zero mean a gaussian noise will have amplitude in the range [-0.5,+0.5] rather than in [0.5,1.5] | T | The Gaussian probability distribution peaks at 0, thus probability is higher in an interval centered in 0 (when both intervals have the same width). |
| 20 | The Central Limit Theorem (CLT) states that the average of $N$ zero-mean independent identically distributed signals approaches zero for $N \to \infty$. | T | TRUE |
| 21 | The DFT of a signal represents the amplitude $A_i$ and initial phases $\phi_i$ of sinewave components of the signal at frequencies $f_i$ ranging from $0Hz$ (included) to the sampling frequency (excluded). | T | TRUE |
| 22 | The frequency response of a filter in the stopband should be plotted in a graph whose vertical axis has a logarithmic scale (i.e. the gain is expressed in dB). | T | TRUE |
| 23 | An IIR filter can be designed to have “linear phase”, so that they do not introduce time-domain distortions in the waveform of the output signal. | F | IIR filters cannot be designed to have liner phase |
| 24 | The amplitude of a P300 event related potential be voluntarily modulated through the exercise of motor imagery, to build a cursor control based on a BCI. | F | Through motor imagery an individual can learn to modulate sensorimotor rhythms, not ERPs |