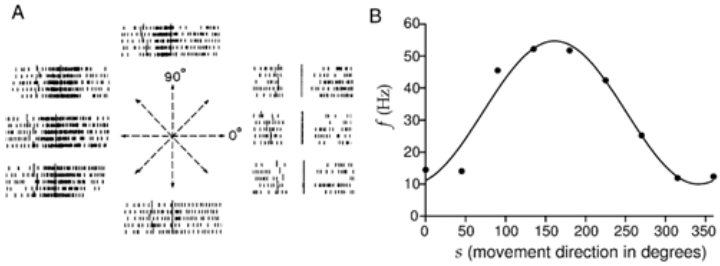
Neuroengineering 2023-2024

Exam 3 July 2024 – Part I (odd)

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 voltage-gated Na^+ channel is responsible for the repolarization phase of the action potential.	F	*The repolarization phase of the action potential is due to the opening of the voltage-gated K^+ channel.*
3	Temporal and spatial summation can occur simultaneously.	T	
4	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.*
5	The frontal lobe houses the primary visual function.	F	*The primary visual cortex is located in the occipital lobe.*
6	In the brain primary motor cortex (Penfield homunculus) the extension of the cortical region which controls a specific body region is proportional to that body region's volume.	F	*The extension of the cortical region which controls a specific body region is proportional to the number of motor nerves, not to the body region's volume.*

#	Question	Ans.	Explanation
7	The long-term synaptic plasticity involves a structural change in the post-synaptic membrane.	T	
8	The brain operates at the temporal scale of milliseconds.	T	
9	The neurons' spatial orientation affects the amplitude of EEG signals	T	
10.	The synchronicity of the neural activity affects the amplitude of EEG signals.	T	
11	Scalp EEG is mainly produced by deep (subcortical) regions.	F	*It is mainly produced by cortical regions.*
12	The electrical variation of the membrane potential that mainly contributes to EEG is the action potential.	F	*The synchronous variations of post-synaptic potentials (and their extracellular counterpart) are the main contributors to EEG signals.*
13	 The tuning curve in the figure shows (panel A) the spike trains obtained - for different trials - from a neuron of the primary motor cortex in correspondence to an arm movement, and (panel B) the firing rate *f* of the same neuron as a function of the angle *s* of the same movement direction. When the firing rate is 55 Hz, I can infer which movement direction produced that response.	T	*Yes, because there's a unique value of s that can produce a neuronal response with that firing rate.*
14	In reference to the previous figure: from the curve I can conclude that this neuron is tuned to be more active in correspondence to a specific movement direction.	T	
15	In reference to the previous figure: the firing rate *f* in panel B was computed as the average of the neural response function across trials.	T	

#	Question	Ans.	Explanation
16	If $C_{xy}(f)$ is the Ordinary Coherence between x and y, $C_{xy}(f)=C_{yx}(f)$.	T	
17	Given the Granger Index G_{xy} between two time series x and y, a negative value of $G_{x \to y}$ means an inverse precedence between the two time series.	F	*A negative value of $G_{x \to y}$ means that the residual of the bivariate model is higher than in the simple model, which is probably due to an incorrect modeling.*
18	In the event of data paucity, the Partial Directed Coherence (PDC) is the most accurate estimator of causality in the statistical sense.	F	*When we have a limited amount of data, PDC returns inaccurate results due to the low ratio between data samples and model parameters.*
19	In an undirected graph, I cannot compute the indegree and the outdegree.	T	*In an undirected graph, there are no directions. Therefore, the concept of "in-degree" and "out-degree" is meaningless.*
20	Random networks have a smaller Local Efficiency than regular (lattice) networks.	T	
21	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.*
22	Divisibility and Modularity are measures of segregation of a network.	T	
23	Regular networks have a smaller Global Efficiency than random networks.	T	
24	Undirected graphs are associated with symmetrical adjacency matrices.	T	

Section B

#	Question	Ans.	Explanation
1	The roll-off of a filter is the slope of its frequency response in the transition band. It is high when the transition band is narrow.	T	TRUE
2	The Short Time Fourier Transform (STFT) is a simple method to estimate a spectrogram, i.e. the representation of the time-varying spectrum of a non-stationary signal.	T	TRUE
3	The N20 component of an EP occurs before the stimulus (negative latency) while the P300 occurs after the stimulus (positive latency).	F	'N' and 'P' indicate the sign of the amplitude of the ERP (Negative and Positive, respectively), not the latency.
4	Event-Related Desynchronization/Synchronization (ERD/S) quantify phase-locked brain activity in response to an event	F	Event-Related Desynchronization/Synchronization (ERD/S) quantify relative changes of the power of the EEG rhythm in a predefined frequency range; phase locked activity is estimated using the synchronized averaging.
5	In ERP analysis, 'trials' are portions of the continuous EEG recording that start exactly at the time when a sensory stimulus was delivered	F	The start of a trial usually precedes the time of the event, so that a pre-stimulus baseline period can be analyzed. Events are not necessarily sensory stimulations.
6	The CMRR of an EEG amplifier should be higher than 90 dB	T	TRUE
7	A 'run' is a portion of recording in an experimental protocol that contains no breaks, i.e. all samples contained therein have been acquired $1/f_s$ seconds after the previous (f_s being the sampling frequency)	T	TRUE
8	EEG signals recorded in monopolar configuration can be re-referenced to the Common Average Reference (CAR), by subtracting from each channel the instantaneous average of all channels. In ideal conditions, this would approximate taking the reference potential at infinity.	T	TRUE

#	Question	Ans.	Explanation
9	The powerline noise affects a very narrow frequency band of the recorded signal around 50 Hz (in Europe) and odd multiples of (150 Hz, 250 Hz, …).	T	TRUE
10	The RMS and the ARV of a zero-mean signal have the same value (assume that the number of samples $N \to \infty$).	F	For a zero-mean signal, the RMS equals the standard deviation σ of a zero-mean signal.
11	An EEG recording is said to be bipolar when it comprises exactly two channels	F	In bipolar EEG recordings, each channel is the difference of potential between two (adjacent) electrodes. The number of channels is not relevant
12	The Shannon's theorem states that a continuous signal can be properly sampled only if it does not contain frequency components above the sampling rate.	F	The signal must not contain spectral components above *half* the sampling rate (Nyquist frequency)
13	Movements of the subject's head produces artifacts only in the gamma band.	F	Movement of the subject's head may produce slow artifacts on the EEG recording, whose waveform is closely related to the timecourse of the movement
14	Evoked Potentials are deflection of the EEG signal following the presentation of a sensory input.	T	TRUE
15	The frequency spectrum of white noise is flat, i.e. it has the same power at any frequency.	T	TRUE
16	The mu rhythm and the alpha rhythm are EEG components that differ for their fundamental frequency of oscillation	F	They both oscillate around 10 Hz.
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
18	When recording EPs, the spontaneous EEG is to be considered a noise that completely masks the EPs on the recorded waveform.	T	True. With very rare exceptions (mostly in the field of pathology) EPs are one or more orders of magnitude smaller than the spontaneous EEG.
19	In a P300-based BCI, the user subjectively assigns saliency (relevance) to a stimulus so that their brain produces a P300 ERP every time the stimulus is administered	T	TRUE

#	Question	Ans.	Explanation
20	The contact impedances of a pair of electrodes should be large compared to the input impedance of the differential amplifier connected to them, otherwise the amplitude of the signal would be reduced as effect of the potential divider.	F	False, the contact impedances must be *lower* than the amplifier's input impedance, mainly to help keeping the circuit balanced (higher CMRR)
21	A FIR filter needs to be of a higher order to achieve the same quality specifications than a IIR filter.	T	TRUE
22	Event-Related Desynchronization/ Synchronization (ERD/S) quantify the amount of coupling between signals on two EEG channels.	F	ERD/S quantify changes of the power of EEG relative to a baseline period
23	$ARV_x = \sqrt{\frac{1}{N}\sum_i (x[i])^2}$, 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
24	Aliasing occurs when an artifact corrupts an otherwise healthy EEG recording.	F	Aliasing occurs when the sampling frequency of an analog signal is lower than twice the frequency of any spectral component of the signal