Neuroengineering 2019-2020

Exam of 9 February 2021 – Part B

Solutions

Section B.1

	Question	Pts.	Ans.	Explanation
1	The frequency of oscillation of the beta rhythm is around 10 Hz	0.5	F	The minimum conventional oscillation frequency of the beta rhythm is 14 Hz
2	Evoked Potentials are deflection of the EEG signal following the presentation of a sensory input.	0.5	T	True
3	EEG electrodes made of gold allow recording of extremely slow-changing potentials.	0.5	F	Gold electrodes are *polarizable*, thus the opposite is true
4	The CMRR is usually expressed in decibel (dB) and high values characterizes better amplifiers.	0.5	T	True
5	The difference of contact impedances of electrodes should be large compared to the input difference of the differential amplifier, otherwise the amplitude of the signal would be reduced (shortcut).	0.5	F	False, the contact impedances must be lower than the amplifier's input impedance, to help keeping the circuit balanced (higher CMRR)
6	In monopolar EEG recordings, the reference electrode is placed on scalp position that are *assumed* to be far from the electrical sources of interest, such as the earlobes.	0.5	T	True
7	The amplitude of the electromyogram (EMG) originated from muscles never exceed $10\ \mu V$.	0.5	F	EMG can be ten times higher than EEG, and exceed 1 mV
8	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, …).	0.5	T	True
9	Movement of the subject's head may produce slow artifacts that are less pronounced when non-polarizable electrodes are used	0.5	T	True
10	The amplitude of ERPs is measured with respect to a baseline epoch (usually preceding the stimulus), in which the amplitude is assumed to be zero.	0.5	T	True
11	The SOA is always smaller than the ISI	0.5	F	False, The SOA equals the ISI plus the duration of the stimulus
12	Brain activity in response to a stimulus can be non-phase-locked, meaning that they show variable latency (jitter) at each repetition. This activity is called *induced*.	0.5	T	True

	Question	Pts.	Ans.	Explanation
13	Event-Related Desynchronization/Synchronization (ERD/S) quantify relative changes of the power of the EEG rhythm in a predefined frequency range, relative to a baseline period.	0.5	T	True
14	The reconstruction of an analog signal from its sampled version is equivalent to the sum a set of a set of $sinc()$ functions, one for each sample.	0.5	T	True
15	In an ADC, quantization introduces a noise whose amplitude is proportional to the width of the quantization interval: $\sigma_{quant} = 1/\sqrt{12}\ LSB$	0.5	T	True
16	Appropriate application of a high-pass digital filter may prevent saturation by removing high amplitude slow artifacts.	0.5	F	False, saturation can be prevented only by applying an analog filter before A/D conversion
17	The sample variance of a signal is given by $s_X^2 = \frac{1}{N-1}\sum_i (x_i - \bar{X})^2$, where the sum extends on the N samples of the signal X	0.5	T	True
18	In a gaussian noise, the probability density that a sample has a given amplitude value follows the normal distribution with zero mean.	0.5	T	A gaussian noise has normal distribution of amplitude of the samples. [*A white noise has a flat spectrum.*]
19	The synchronized average of N trials containing only spontaneous EEG whose $RMS_{trial} = \sigma^2$ is a signal $RMS_{avg} = \sigma^2/N$	0.5	T	True
20	The spectral leakage phenomenon is observed, for instance, when comparing the spectrum of a signal with the spectrum of a short section of the same signal.	0.5	T	True
21	The Butterworth filter is a design method in the family of Finite Impulse Response filters	0.5	F	A Butterworth filter is a IIR filter.
22	The P300 ERP generated by attending a target stimulus is exploited to build virtual keyboards based on a BCI	0.5	T	True
	Total points	**11**		

Problem B

A P300 event-related potential (ERP) is elicited by means of a "oddball" paradigm, i.e. delivering to the subject a train of stimuli randomly chosen between two option. In this experiment, the stimuli were visual and consisted of either an 'O' or a 'X' presented on a computer screen, with the timing shown in *Figure B1(A)*. EEG potentials are recorded on three scalp electrodes, segmented into trials, and selectively averaged. The waveforms in *Figure B1(B)* correspond to the average of the 'X' stimuli only, which is presented with a probability P=20%. Also check the information embedded in *Figure B1*.

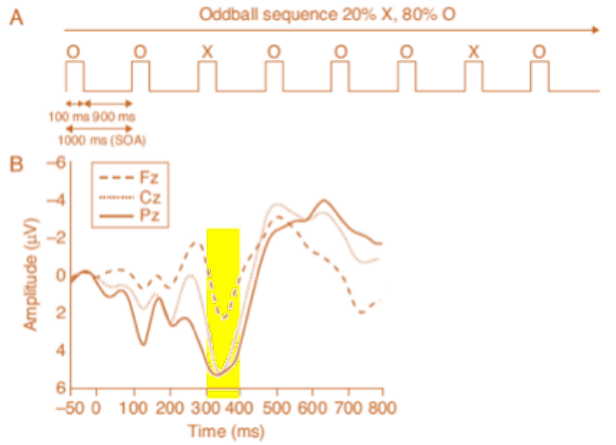

Figure B1. (A) Timeline of the experimental paradigm, showing trials containing 'O' and 'X' stimuli
(B) Synchronized averages of 'X' trials.

Questions:

B1. Would a high-pass filter with cutoff frequency at 30 Hz significantly affect the amplitude of the ERPs? Justify in max 2 lines.

Answer B1

Answer: Yes

Justification:

All components of the ERP have a frequency lower than 30 Hz (or equivalently, a period longer than $1/\ 30Hz = 33.3\ ms$) and thus are attenuated by the filter.

B2. Determine the latency of the P300 component on a frontal channel. Describe the measurement process in max 2 lines.

Answer B2

Latency: ~350 ms

Explanation:

It is the latency of the lowest point of the dashed line (Fz, a frontal channel).

(See also the vertical marker in the figure below.)

B3. Determine the amplitude of the P300 component on each channel. State whether the ERP more positive on the anterior or posterior part of the scalp.

Answer B3

Amplitudes: Fz= +2 μV; Cz= +5 μV; Pz=+5 μV

Statement: The amplitude is more positive on the posterior part of the scalp.

(See also the horizontal markers in the figure below. Note that the amplitude axis is positive-down.)

B4. How long would the data recording session last if we need to reduce the amplitude of the spontaneous EEG by a factor of K=10 with respect to the unaveraged trial?.
Justify in max 5 lines.

Answer B4

Duration: 8 minutes and 20 seconds

Justification:

We need $K^2 = 100$ trials with 'X' stimulus, thus $K^2/P = 500$ total trials. The total duration is $SOA \cdot K^2/P = 500\ s = 8'20"$ (The SOA must be used rather than the ITI, otherwise the trial duration is underestimated by the 'on' time of the stimulus).

B5. Since only 20% of the trials contain a 'X' stimulus, could the experimenter increase the signal to noise ratio of the ERP by raising the proportion of X's to 80% (thus increasing the number of useful trials)?
Justify in max 5 lines.

Answer B5

Answer: No

It is true that having a larger number of trials reduces the denominator of the signal-to-noise ratio. On the other hand, P300 is always elicited by the unpredicted (rare) events. If the proportion of the "rare" stimulus is increased close to or above the chance level (50%), the brain does not respond anymore with a P300 potential, thus the numerator of the signal-to-noise ratio is reduced by an even greater amount.

(Note that since the proportions (20%-80%) are swapped between stimuli, the very same P300 potential might be obtained in this case by averaging the 'O' stimuli.)