Neuroengineering 2021-2022

Exam of 23 June 2022 – Part II

Solutions - *Even seats*

Problem

During the planning and execution of a motor task, a characteristic EEG response (ERP) is produced, known as the motor-related cortical potential (MRCP). The early components of the MRCP are associated with preparation for movement execution.

Motor task.
A motor target task was displayed on a PC that required an accurate 14-cm linear movement in the horizontal plane, from the center of the workspace to a target placed in a direction directly away from the subject, and was accomplished using shoulder flexion and elbow extension of the right arm.
Four runs of task containing 40 trials each were interleaved with 2 minutes of rest.

EEG Data acquisition.
Simultaneous data was obtained for EEG, EMG, and movement onset (the latter via a custom movement detection device). A commercial system and software were used to acquire and process surface EEG signals. Electrodes were placed in the positions of the International 10–20 System, excluding all frontopolar (Fp) and occipital (O) channels. Impedance at lower than 10000 Ω was obtained prior to data collection. The active electrodes were referenced to the common linked left and right mastoid surface electrodes. EEG signals were amplified (×75 000), low-pass filtered (0–300 Hz), and digitized (400 sample/s).
In addition to dataset acquired for the experimental (motor) task, one run of rest with open eyes (1 minute), one run of rest with closed eyes (1 minute) were acquired.

Motor-Related Cortical Potential (MRCP)
Raw signal recordings were visually inspected to detect artifacts induced by eye blinks, facial muscle contractions, or head movements and removed either manually or with software filters; otherwise, the trials were discarded if noise or artifacts were not correctable. Trials containing noise from EMG signals were discarded.
MRCP was derived from movement onset trigger-averaged EEG signals. The EEG signal included an 8-s window (4 s before and 4 s after the onset event). The mean MRCP start time and amplitude were calculated for each electrode. We defined cognitive effort level as MRCP amplitude (μV; *Figure 1*) and cognitive planning time as the duration of time between MRCP onset and EMG onset (*Figure 1*).

EMG data acquisition
The EMG signal was acquired using bipolar electrodes (8-mm recording area) applied on the anterior deltoid and triceps, agonist muscles. EMG onset time was defined as: 2 standard deviations (SD) increase in amplitude above the resting baseline that was maintained for at least 100 ms. The EMG signal was amplified (×1000), filtered 10–2000 Hz, digitized (5000 samples/s), and synchronized with EEG.

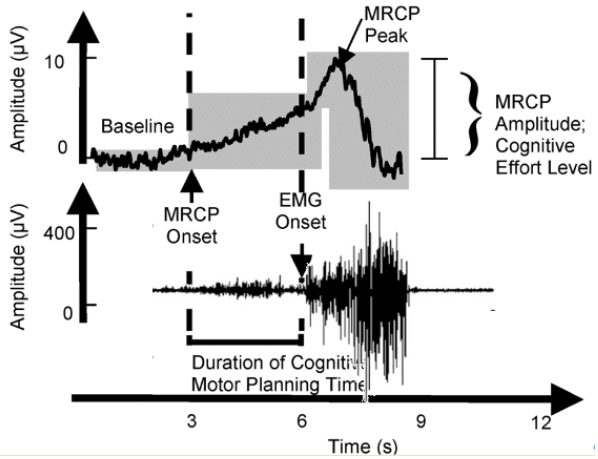

Figure 1. Top graph shows schematic of MRCP, characteristic EEG signal present prior to and during performance of motor task. Vertical axis shows amplitude of signal and horizontal axis represents time (in seconds). First 3 s shows baseline EEG signal. MRCP onset is labeled at 3 s with upward vertical arrow. Vertical distance from baseline to MRCP peak is labeled as "MRCP amplitude" or "cognitive effort level." bottom graph shows schematic of EMG signal, and EMG onset is labeled at 6 s with downward vertical arrow and associated vertical line (vertical dotted line on right). MRCP onset is indicated across both top and bottom graphs with vertical dotted line on left at 3 s. Duration of cognitive planning time is horizontal solid line between MRCP onset (3 s) and EMG onset (6 s).

Questions:

Q1. Regarding the acquired EEG channels:

a. Following the experiment's description from the paper, how many EEG channels were acquired?
b. How many electrodes had to be mounted on the subject's head?
c. If only the following four bipolar channels were acquired in the experiment, how many electrodes should have been mounted on the subject's head?
T7-C3, C3-Cz, Cz-C4, C4-T8
Justify each answer in max 10 lines total.

Answer Q1

a) number of channels: 15
b) number of channels: 18
c) number of channels: 6
Justification:
a) EEG collection according to the International 10-20 System, which specifies the position of 19 electrodes, of which 2 are frontopolar and 2 are occipital (the recording was monopolar, being later specified what -common- reference was used).
b) 15 active electrodes, + 2 reference electrodes ("common linked left and right mastoid") + 1 ground electrode
c) 5 active/reference electrodes (T7, C4, Cz, C4, T8) + 1 ground

Q2. Is there any inconsistency or mistake in the description of EEG signals Analog-to-Digital conversion? What about the EMG signal?
Justify in max 5 lines.

Answer Q2

Mistakes: Corner frequency of the antialiasing filter at 300 Hz.

Justification:
No obvious mistakes for the EMG conversion.
The analog low-pass frequency must be lower than the Nyquist frequency (=200 Hz, half the sampling frequency).

Q3. Assuming the amplitude (RMS) of the raw EEG on channel is 25µV, compute the expected noise on the ERP due to spontaneous EEG activity.
Justify in max 5 lines.

Answer Q3
Noise amplitude: $1.976\ \mu V$
Justification:
The task was composed of "*Four runs of task containing 40 trials*", i.e. $N = 160$ trials. The amplitude of the residual spontaneous EEG in the average of N trials is $\sigma_{avg} = \sigma_{raw}/\sqrt{N} = 25/12.65\ \mu V = 1.976\ \mu V$

Q4. Analyzing *Figure 1*, and considering the EMG onset as the relevant event (zerotime), what is the latency of the MRCP onset? What is the latency of the MRCP peak?
Justify in max 5 lines.

Answer Q4
MRCP onset latency: $-3\ s$ (or $-3000\ ms$)
MRCP peak latency: $+1\ s$ (or $+1000\ ms$)
Justification:
The MRCP onset takes place 3 s before the EMG onset. The MRCP peak takes place 1 s after the EMG onset.

Q5. Is the EMG represented in *Figure 1* the raw signal or was it processed? If so, what processing steps were presumably done to obtain the graph?
Justify in max 5 lines.

Answer Q5
Is EMG raw?: yes (presumably)
Justification:
The signal is either raw or, at most, has been processed with a broadband high-pass filter. It was not rectified, nor its envelope was extracted. No feature extraction was performed.

Q6. The technician misnamed the files with the rest EEG runs, and now he is not sure which was acquired with the subject's eyes open and which with the eyes closed. Would you be able to tell them apart? If so, would visual inspection sufficient or would you need to process the data?
Justify in max 5 lines.

Answer Q6
Are data runs identifiable? : Yes
Justification:
In most subjects, one can observe the increased amplitude of the alpha rhythm in the eyes-closed condition with respect to the eyes-open condition, by visual inspection of the raw EEG. The parieto-occipital and occipital channels show the synchronization most clearly (see slides about the alpha blocking phenomenon), but the visual alpha rhythm can also be seen on parietal channels, even though with worse

SNR.
Alternatively, one could seek blink artifacts on frontal channels, which would indicate an eyes-open condition. (Prefrontal channels would have been chosen, if they were available.)

Q7. Which EEG channel was likely represented in Figure1? Indicate a channel name or a set of possible channels.
Justify in max 5 lines.

Answer Q7
Displayed channel (or reasonable set): C3 (or electrodes nearby, e.g. C5, P3, etc.)
Justification:
We can expect that a motor related potential is maximally visible on the sensorimotor area of the contralateral hemisphere. Since the motor task was "shoulder flexion and elbow extension of the right arm", we can thus speculate that the authors used a central (or centroparietal) channel of the left hemisphere, near the cortical representation of the arm, thus in the neighborhood of C3.