Neuroengineering 2021-2022

Exam 23 June 2022 – Part II (even seats)

How to submit your answers.

Most answers can be typed in the Exam.net editor.
Write the answers in the same sequence as the questions (Q1, Q2, …) and write the same headers as the test on a separate line just above your answer, e.g.:

> Problem
> Q1
> *<your answer to question Q1 goes here>*
> Q2
> *<your answer to question Q2 goes here>*
> …

Textual answers must be typed in the editor. When graphical elements are required in the answer, the latter can be written on paper and scanned using your mobile phone at the end of the exam.
It should always be possible to use a single sheet of paper for all answers to a specific problem. Anyway, always use separate sheets of paper for problems A and B.

Keep your answers tidy. Messy, hard-to-read answers may penalize your mark.

Your answers should not exceed the length recommended in each question.
Answers significantly longer than requested may reflect poor understanding of the problem, and thus will likely receive a lower mark.

The maximum total score for part II is 11.

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 and questions on the following pages)

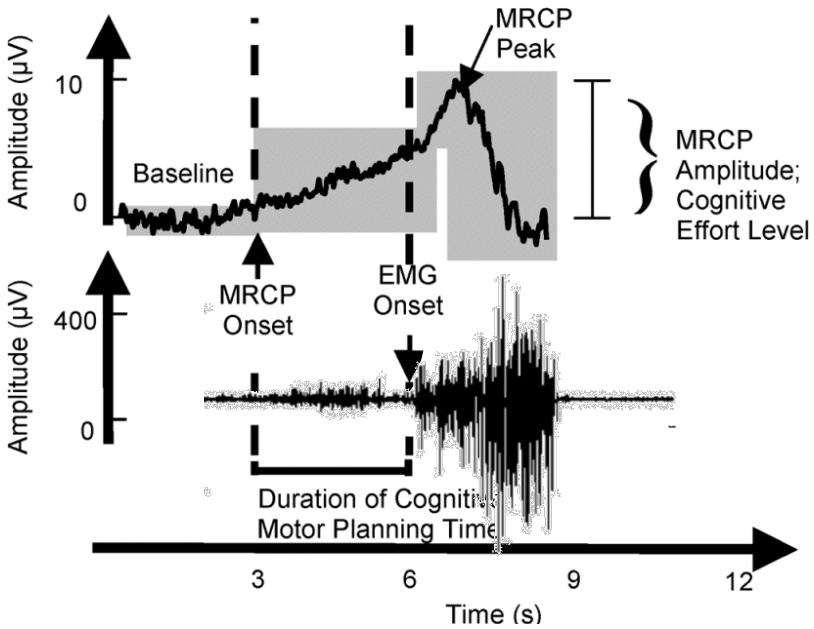

Figure 1. Top graph shows schematic of MRCP, characteristic EEG signal present prior to and during performance of motor task. Vertical axis shows amplitude of signal and horizontal axis represents time (in seconds). First 3 s shows baseline EEG signal. MRCP onset is labeled at 3 s with upward vertical 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-Q7):

Type all answers in the exam.net editor, following the prepared template.

Mathematical formulas or drawings can be handwritten and a reference to the scan can be included in the answer.

Q1. Regarding the acquired EEG channels:

a. *(1 point)* Following the experiment's description from the paper, how many EEG channels were acquired?

b. *(1 point)* How many electrodes had to be mounted on the subject's head?

c. *(1 point)* 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.

Q2. *(1 point)* 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.

Q3. *(1 point)* 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.

Q4. *(1 point)* 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.

Q5. *(2 points)* 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.

Q6. *(1 points)* 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.

Q7. *(2 points)* Which EEG channel was likely represented in Figure1? Indicate a channel name or a set of possible channels.
Justify in max 5 lines.