BSP 2021-2022/1 - Assignment 04

Total of 10 marks

Name/Neptun Code: <u>Csomai Borbála/ZZMDFE</u>

Marks attained for this homework will count towards your final grade

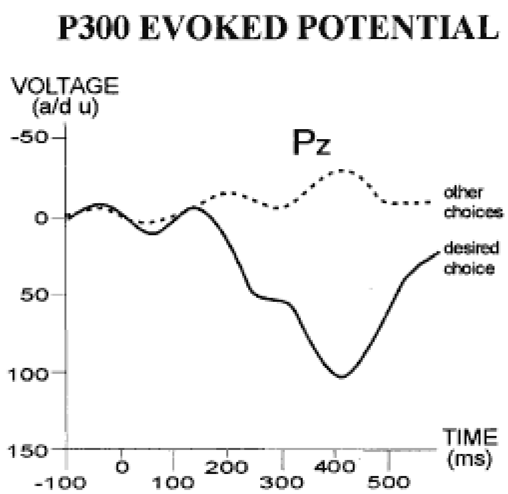
To attain (full) marks for a question, any answer that includes images or a piece of knowledge, which should be referenced/cited, needs to highlight the source (book, article or web address). You are encouraged to help each other, but identical solutions will not be graded.

The P300, "oddball" paradigm

Watch the video: link to video

Protocol: in a sequence standard and deviant tones are played for the participant. The deviant sound is different in frequency and amplitude. The listener has to push a button when a deviant sound is detected.

The P300 evoked potential is a positive response (mind the axes below) on the EEG signal at 300 ms, corresponding to the anticipation of the deviant tone.



However, we do know that EEG signals are extreamly noisy, as we are working with very low-apmplitude signals. For this reason, a single measurement cannot detect this change. In the protocol the EEG response is recorded multiple times, and a synchronized averaging is performed on the 'standard' and 'deviant' measurements.

The signal

The data contains 3 columns:

1. BNC - the sound tones

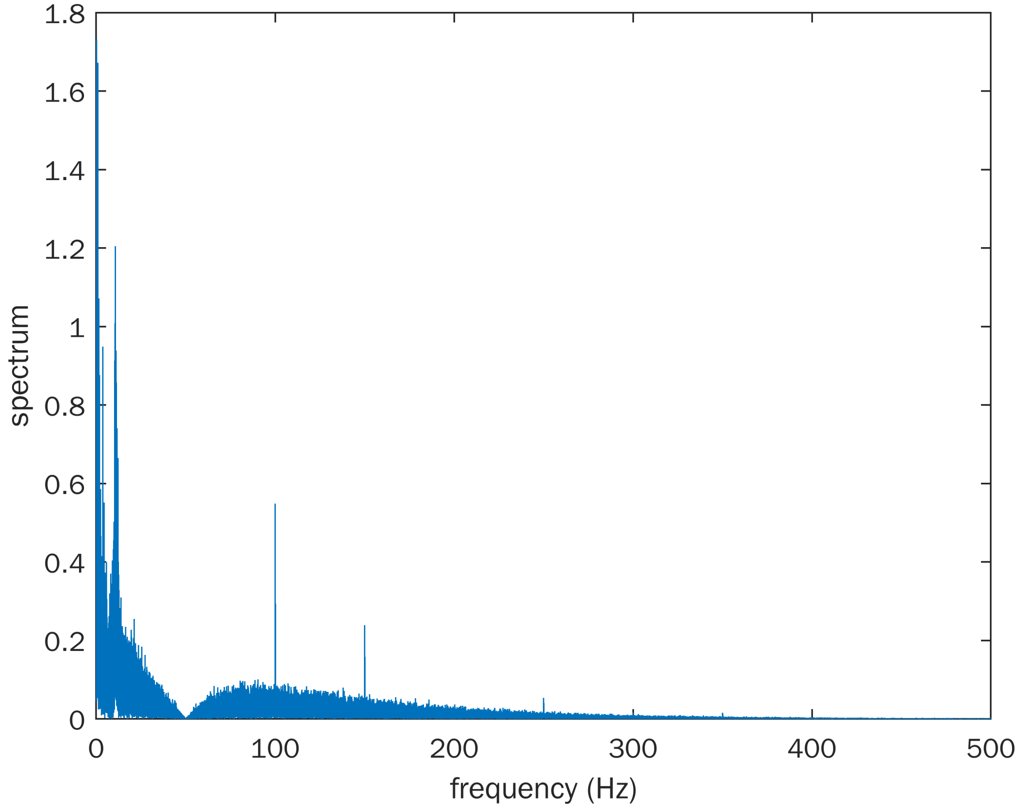
2. EEG
3. the button pushes

The measurement started at 178 s after the recording was turned on. Cut the first 178 s from all 3 columns, and plot the spectrum of the EEG signal, if the sampling frequency was 2 kHz.

```
clear clc;
load BSP_P300.mat;
fs = 2000; % Hz
% cropping of the data
data = data(178*fs:end, :);
Ns = size(data,1); % number of samples

BNC = data(:,1);
EEG = data(:,2);
Button = data(:,3);

% time array
t = linspace(0, (Ns-1)/fs , Ns);
% frequency array
f = linspace(0, fs/2, Ns/2+1);
% Spectrum of the EEG signal
fEEG = fft(EEG);

P2 = abs(fEEG/Ns);
P1 = P2(1:Ns/2+1);
```

```
Warning: Integer operands are required for colon operator when used as index.
```

```
P1(2:end-1) = 2*P1(2:end-1);

figure
plot(f,P1)
xlabel('frequency (Hz)')
xlim([0,500])
ylabel('spectrum')
```



(1 mark)

Question 1

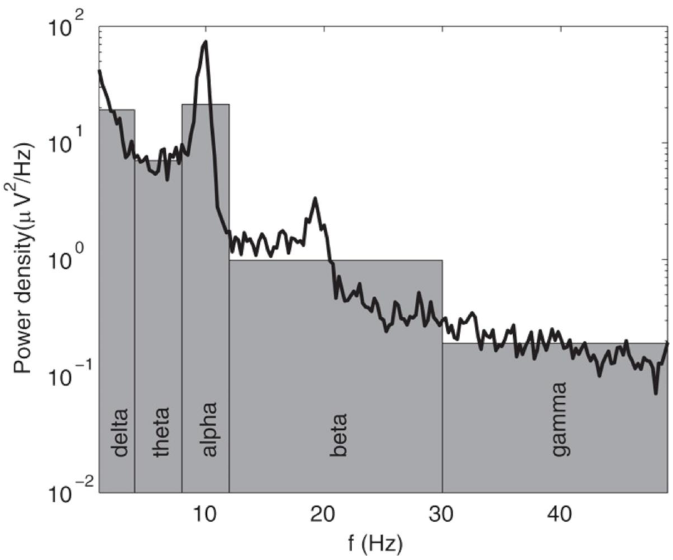
Inspect the plotted spectrum. Explain, what can be seen at 50 Hz, 100 Hz, 150 Hz, etc.

We can see a 'gap' on the spectrum at 50 Hz, this is the value of the powerline interference, so it was probably filtered out. The peaks at 100 Hz, 150 Hz and 250 Hz can also explained by this phenomenon.

(1 mark)

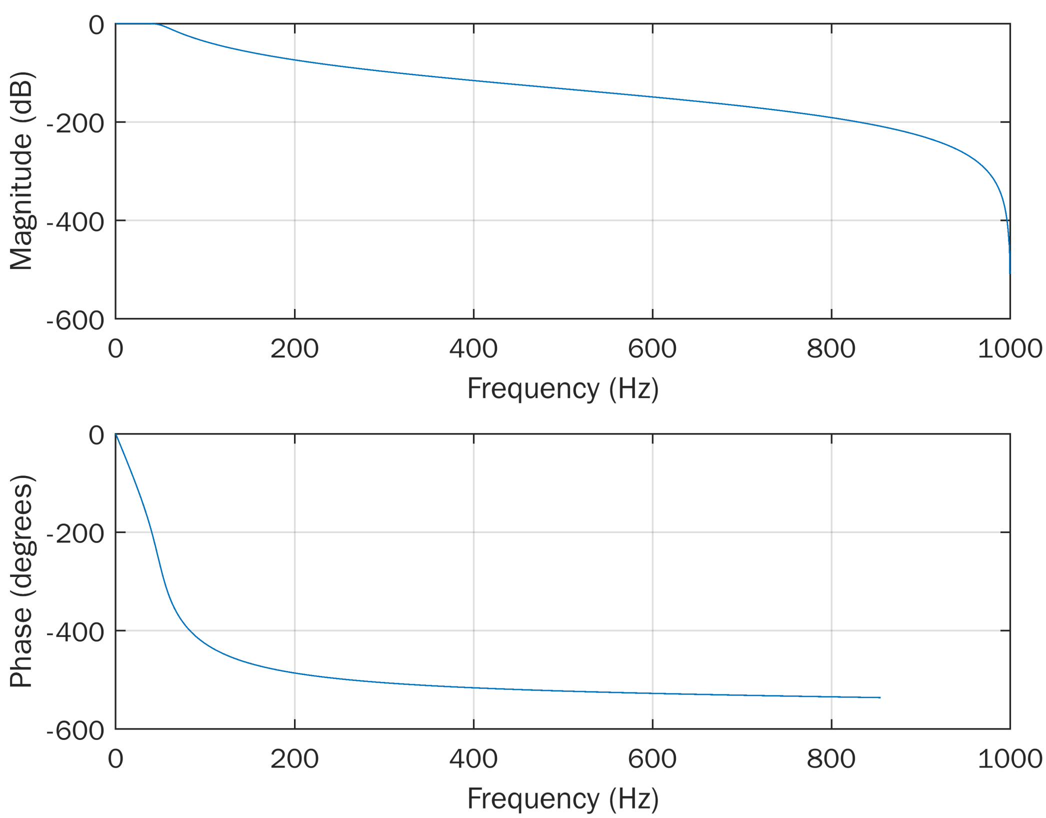
Prefiltering of the signal

Here you can see the characteristic spectrum of an EEG signal.



It is visible that all important EEG information is stored in the <50Hz range. Design a butterworth LPF for eliminating any higher frequency noise.

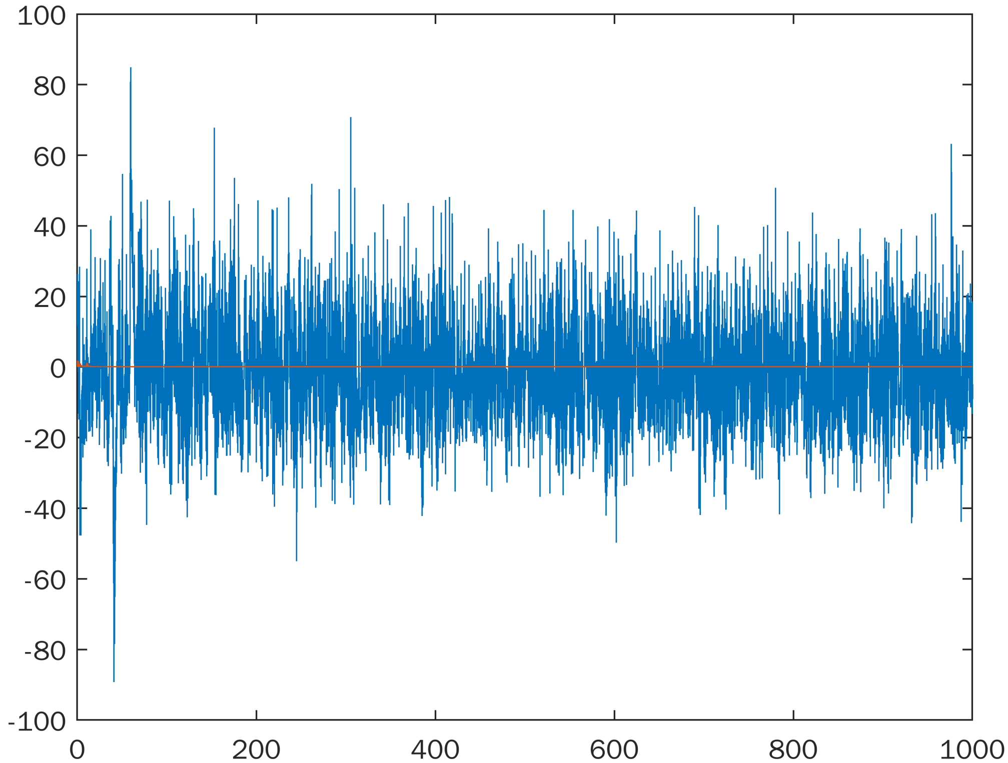
```
fc = 50;
[b,a] =  butter(6,fc/(fs/2), 'low');
% Inspect the Bode diagram of the filter
figure
freqz(b,a,fs,fs);
```



```
% use filtfilt to avoid signal delay
EEG_prefilt = filtfilt(b,a,EEG);

fEEG_prefilt = fft(EEG_prefilt);

P3 = abs(fEEG_prefilt/Ns);
P4 = P3(1:Ns/2+1);
```

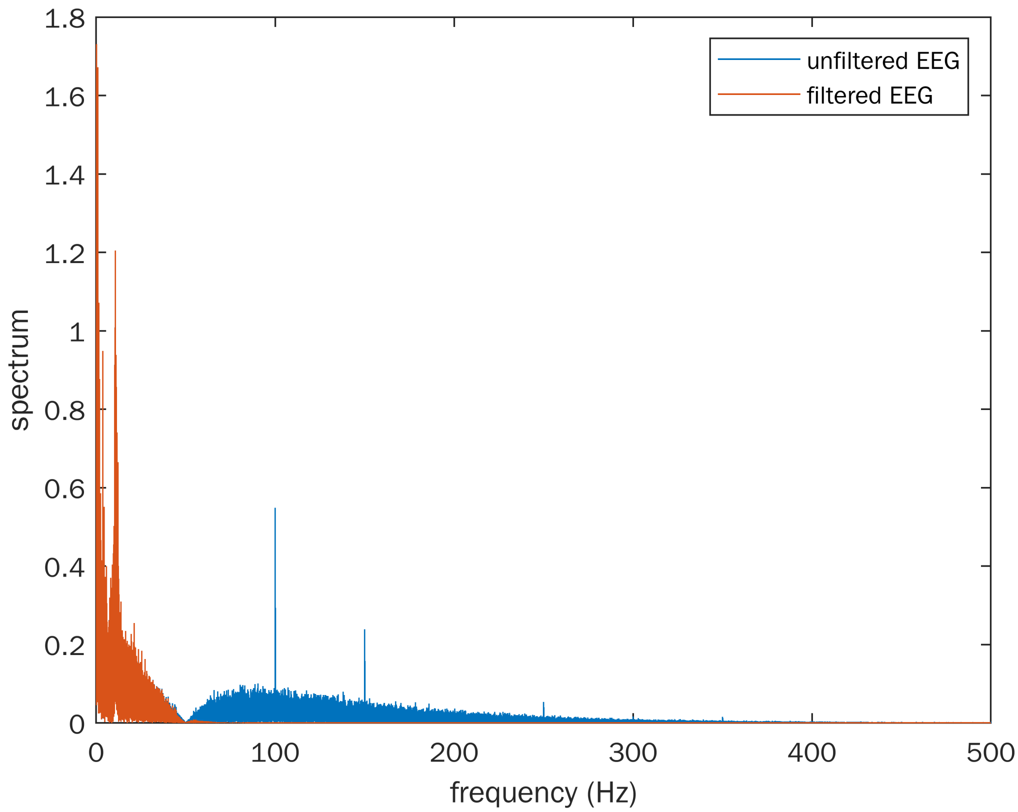
```
Warning: Integer operands are required for colon operator when used as index.
```

```
P4(2:end-1) = 2*P4(2:end-1);

figure
plot(f, EEG_prefilt(1:round(Ns/2)))
hold on;
plot(f,P4(1:round(Ns/2)))
```




```
figure

plot(f,P1)
hold on;
plot(f,P4(1:round(Ns/2)))
xlabel('frequency (Hz)')
xlim([0,500])
ylabel('spectrum')
```

```
legend('unfiltered EEG','filtered EEG')
```



(1 mark)

Question 2

What is the phase response of the filter defined by 'b' and 'a'?

```
ba_respone = "non-linear phase"
```

```
ba_respone =
"non-linear phase"
```

What is the phase response of the filtering, using the filtfilt() function?

```
filtfilt_response = "zero-phase"
```

```
filtfilt_response =
"zero-phase"
```

If a 100 Hz component has a magnitude of 0.1 uV, what will be its amplitde after filtering?

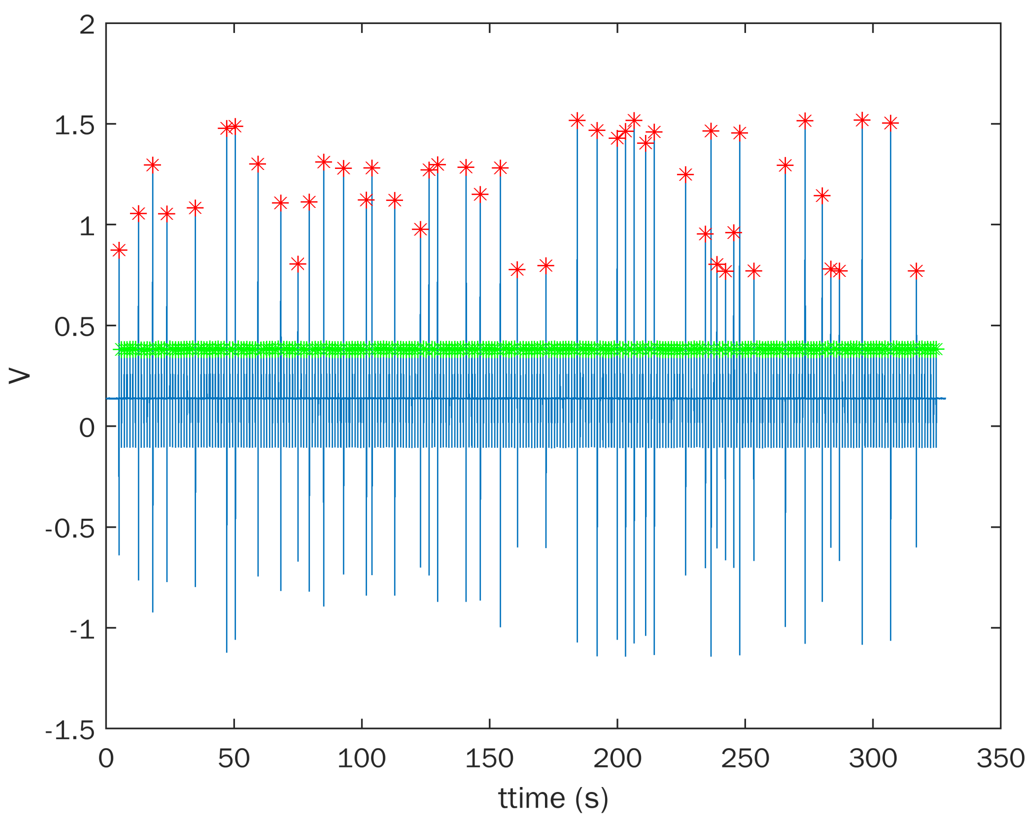
```
% dampened_magnitude = 0.1*
```

(2 marks)

Separating the deviant and standard tones

The deviant tones have an amplitude above 0.5 V, while standard tones are peaking between 0.37 - 0.39 V.

```
figure
plot(t,BNC)
xlabel('ttime (s)')
ylabel('V')

%finding all the peaks
[pks, locs] = findpeaks(BNC,'MinPeakHeight',0.2,"MinPeakDistance",0.5*fs);
hold on
plot(t(locs),pks,'k*')

% picking only the higher amplitude, deviant peaks
dev_locs = locs(pks> 0.5); %%
dev_pks = pks(pks>0.5); %%
plot(t(dev_locs),dev_pks,'r*')

% picking only the lower amplitude, standard peaks
std_locs = locs(pks< 0.39); %%
std_pks = pks(pks<0.39); %%
plot(t(std_locs),std_pks,'g*')
```



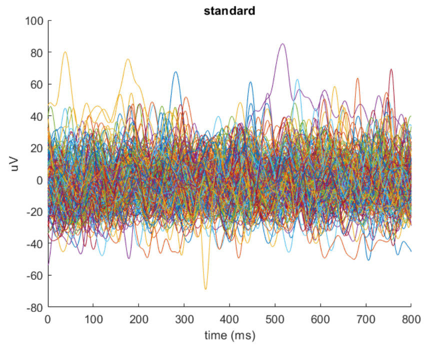
(1 mark)

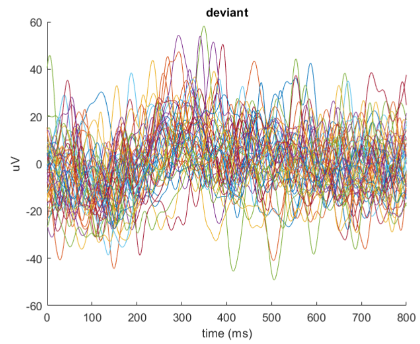
Averaging the deviant and standard EEG snippets

The tones located above signal the onset, '0 s' for the P300 signal. These will help us to do the synchronized averaging, this is the 'synchronous event'.

Use the std_locs and dev_locs arrays for finding the corresponding EEG_prefilt snippets. Cut 800 ms sections of the EEG_prefilt signal.

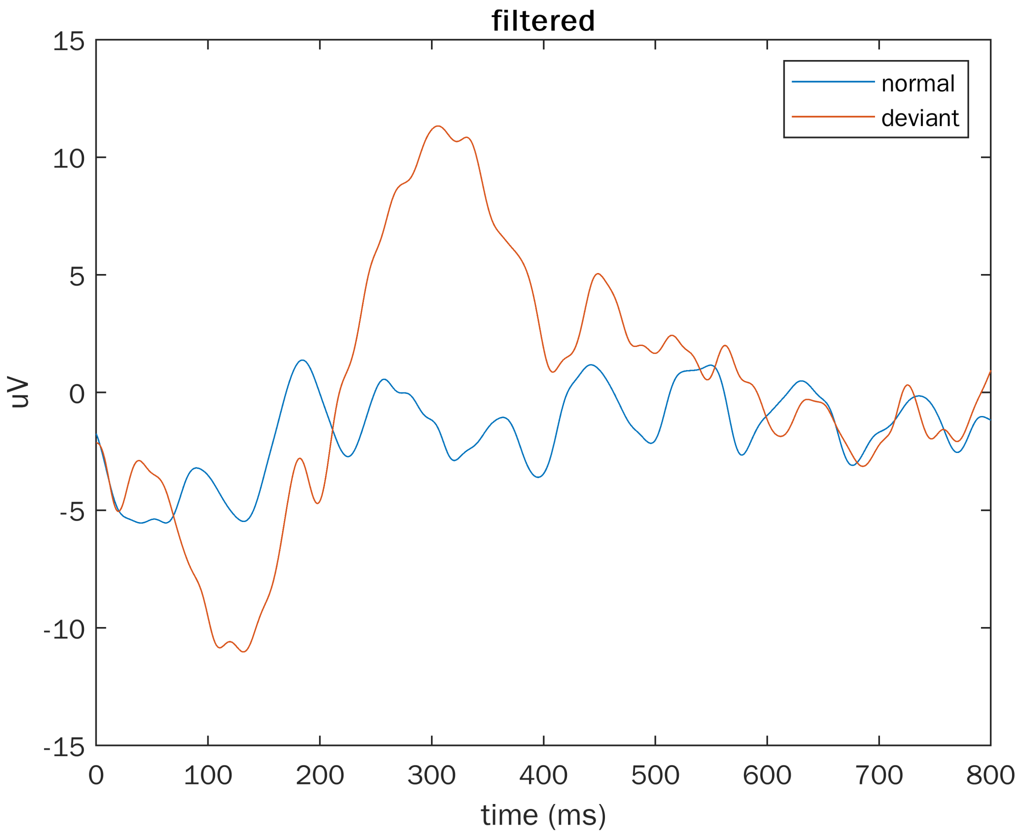
Without averaging, the segments look like this:





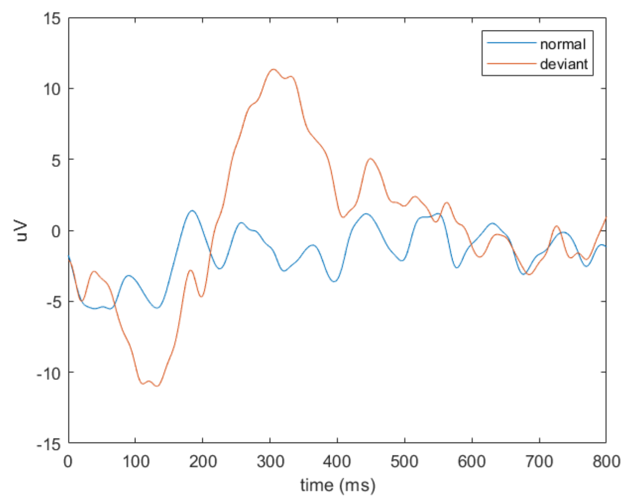
For showing the P300 shift properly, these segments will have to be averaged.

```
% number of samples in 800 ms-long recording
Np300 = 0.8*fs;

% averaging the standard EEG responses
EEG_std = zeros(1,Np300);
% this might actually be multiple lines...
for i=1:size(std_locs, 1)
    EEG_std(i, :) = EEG_prefilt(std_locs(i, :):std_locs(i, :) + Np300-1);
end
EEG_std = mean(EEG_std, 1);

% averaging the deviant EEG responses
EEG_dev = zeros(1,Np300);
% this might actually be multiple lines...
for i=1:size(dev_locs, 1)
    EEG_dev(i, :) = EEG_prefilt(dev_locs(i, :):dev_locs(i, :) + Np300-1);
end
EEG_dev = mean(EEG_dev, 1);

t_short = linspace(0,Np300/fs,Np300);

figure
plot(t_short*1000,EEG_std)
hold on
plot(t_short*1000,EEG_dev)
legend('normal','deviant')
xlabel('time (ms)')
ylabel('uV')
title('filtered')
```



(2 marks)

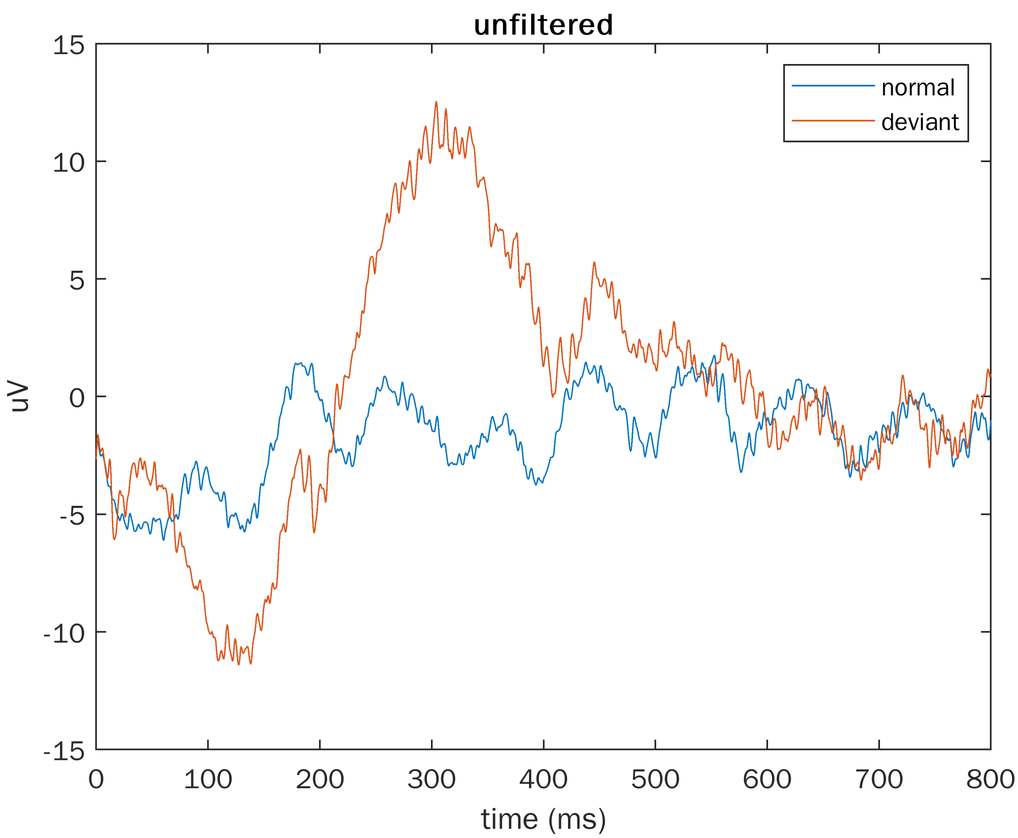
Ideally you should see on the output something similar:



Repeat the previous section with the unfiltered EEG signal. Plot the result.

```
% averaging the standard EEG responses
EEG_std_unf = zeros(1, Np300);
% this might actually be multiple lines...
for i=1:size(std_locs, 1)
    EEG_std_unf(i, :) = EEG(std_locs(i, :):std_locs(i, :) + Np300-1);
end
```

```
EEG_std_unf = mean(EEG_std_unf, 1);

% averaging the deviant EEG responses
EEG_dev_unf = zeros(1, Np300);
% this might actually be multiple lines...
for i=1:size(dev_locs, 1)
    EEG_dev_unf(i, :) = EEG(dev_locs(i, :):dev_locs(i, :) + Np300-1);
end
EEG_dev_unf = mean(EEG_dev_unf, 1);

t_short = linspace(0,Np300/fs,Np300);

figure
plot(t_short*1000,EEG_std_unf)
hold on
plot(t_short*1000,EEG_dev_unf)
legend('normal','deviant')
xlabel('time (ms)')
ylabel('uV')
title('unfiltered')
```



Question 3

Remember the conditions of synchronized averaging. What noise component is causing the difference between the two previous plots? Give an explanation.

<u>We can filter out random noise factors most effectively with the use of synchronized averaging. These appear</u>

in random moments, so when we average a huge set of data, even those components are filtered out, which

show a great difference (high peak), from the raw measurement.

Where is the noise dampening stronger? In the averaged deviant, or standard signal? Why?

The dampening is stronger in the averaged deviant signal. This may be because there are less data points to average

in case of the deviant signal. Averaging less data results in a more visible difference between a noisy and the filtered data.

At the same time, if we look at the first diagram (the filtered data), we can see that the blue curve (with the standard data points) is smoother

than the orange one (with the deviant data points), this is because we averaged more data.

(2 marks)

Do not forget to generate a pdf report from this file (Save/ Export to PDF). You should upload both the pdf and mlx files to moodle.