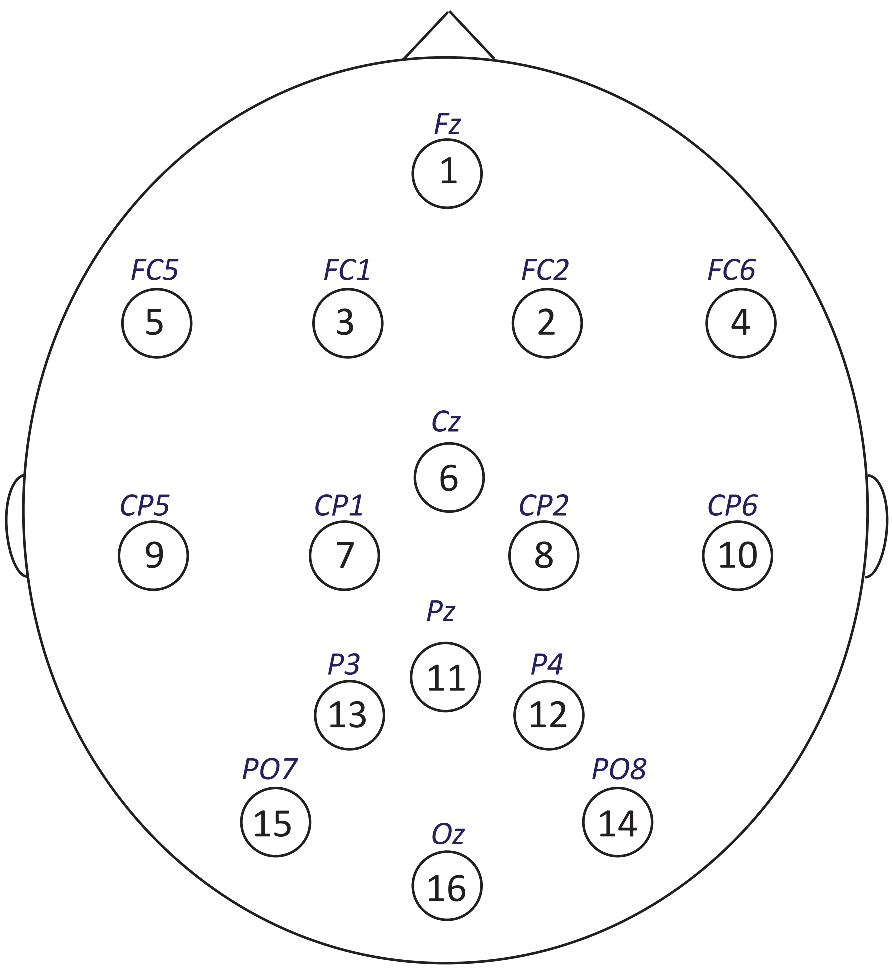
COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

Lab Instruction 6
Auditory Steady State Response

Brain Computer Interface Lab
ECBM 4090



Some materials adapted from g.tec medical engineering (www.gtec.at).

Auditory Steady State Response (ASSR) is an objective test used to evaluate hearing threshold. It involves the neural measurement of a rapidly modulated sound (e.g. tone, noise). In humans, it has been shown that the amplitude of the measured brain signal peaks when the sound is modulated at about 40Hz.

In this project, we will generate an amplitude-modulated tone and record the EEG signal as the subject listens to the sound. We will study the ASSR by measuring the magnitude of the response to the modulator frequency (fm). Unlike ERP, the ASSR is not a time-locked response. The ASSR is measured in the spectral domain.

Setup:

1. Electrodes: **Fz, Cz, Pz, FC1, FC2, CP1, CP2**
2. Filter: bandpass 0.5Hz to 60Hz, notch at 60Hz.
3. The subject should keep their eyes open and fixated, but not on the monitor.

Experiment 1: Measuring ASSR for a 40Hz amplitude modulated tone

1. Create a Simulink s-function.
    a. The function should start playing a continuous sound 15 seconds after the beginning of the experiment to allow the EEG signal to settle.
    b. It should also output a flag at the onset of the sound to be saved to file. The flag can later be used to segment the EEG signal.
    c. **Important**: Make sure the sound is long enough and that it is played only once.
    d. **Reminder**: To get the simulation time use
       >> Ct = get (block , 'CurrentTime');

2. Use your s-function to create a 900Hz tone (carrier frequency, fc) and modulate its amplitude with a 40Hz sinusoid (modulator frequency, fm).
    a. To create a tone with duration d, sampling frequency fs, and frequency f:
       t = (1:d*fs) / fs;
       w = sin (2 * pi * f * t);
    b. To create a tone with carrier frequency 'fc' modulated at frequency 'fm', create two tones with the same duration and sampling rate with frequencies fc and fm.
    c. Multiply the two to get an amplitude-modulated tone.
    d. **Important**: Make sure the modulator tone (fm) is always positive by adding a bias (1 + sin()) to prevent artifacts.
    e. Plot the first 100ms of every sound generated in the experiments **outside** of Simulink (copy and paste your sound generation code into the workspace) to make sure each audio waveform looks and sounds acceptable.

Report: Create a tone at 40Hz and listen to it. Can you hear it? What about a tone at 900Hz? Based on your answer, explain in your report why we need to have carrier (900Hz) and modulator (40Hz) tones. Include a plot of the first 100ms of each sound generated in 2e (carrier, modulator, AM signal). (7 pts)

3. Run the experiment. (NOTE: Check with the TA before conducting the experiment.)
    a. Deliver the tone to the subject binaurally (the same signal in both ears) and collect the EEG data as the subject listens to the sound.
    b. ASSR is a relatively weak signal, so make sure to collect enough data -- at least 10 minutes -- which can be done in multiple blocks if needed.
    c. Your s-function should stop the sound and set the output flag back to 0.
        Hint: If you need to stop playing a sound, use "clear sound" in MATLAB.

Experiment 2: ASSR at 30Hz

1. Repeat the previous experiment, but change the modulator frequency to 30Hz. **Make sure to save the data from this experiment to a different file.**

2. Plot the first 100 ms of each sound you generate and double-check that they sound acceptable.

Report: Include a plot of of the first 100ms of each sound (carrier, modulator, AM signal). (3 pts)

Homework:

Plot the time waveform of **all** the sounds used in your experiments (only 100ms of the signal), and their time-frequency decomposition (a.k.a. a spectrogram. Use MATLAB's spectrogram() function). (1 pts)

Load the EEG signal in MATLAB and use the trigger you generated in your s-function to separate the EEG response only when the sound was playing. Since the tone you played was modulated at a particular frequency, the best way to analyze it is in the frequency domain.
Take the Fourier transform of each channel, and start your analysis by averaging the magnitude of the FFT over all channels.
Plot the average magnitude. You can expect to see a peak at 40Hz in the EEG data. (1 pt)

If the length of the FFT is L, given the sampling frequency of your EEG signal (256Hz), what sample in FFT corresponds to the modulator frequencies you used (40Hz, 30 Hz)? (1 pt)

Use the following command to plot the one-sided spectrum: plot(linspace(0, FS/2,N),f(1:end/2)), and mark the modulator frequencies on the plots for each condition. Measure the normalized ASSR component by dividing the magnitude of the Fourier transform by its sum. Each Fourier coefficient now represents the *relative* power at that frequency, instead of *overall* power. (1 pts)

Next, we will determine how much data is needed to get a good ASSR measurement. To answer this important question, repeat your analysis for cumulative 30s intervals (i.e. first 30s, first 60s, first 90s, …). Display the relative magnitude of the ASSR as a function of signal duration.

At what duration can you reliably detect the presence of the ASSR? Does the signal get stronger the more data you include, or does it reach a plateau after a certain duration? Do you think you collected enough data? If not, how much more do you think you need to reach a plateau? (5 pts)

Measure the ASSR component separately for all channels at the modulator frequency (40Hz in condition 1, 30Hz in condition 2). Use the scalp map to show the relative magnitude of the ASSRs at all electrodes under each experimental condition (30Hz and 40Hz).
Which electrodes recorded the largest ASSR component? (1 pt)