05_UnivariateAnalysis

July 8, 2025

(C) 2025, Gerold Baier, University College London

1 Univariate Analysis of sEEG

1.1 Import and Functions

[49]:
```
from numpy import pi, linspace, sin, diff, arange, asarray, zeros, exp, array,␣
↪linspace, flip

from matplotlib.pyplot import subplots

from scipy.signal import butter, sosfilt
from scipy.fft import rfft, rfftfreq

from pandas import read_csv
```

[51]:
```
def eeg_plot(data, offset, normalise=True):
    """
    Plot date columns in EEG style
    data:       two-dimensional array
    offset:     scaling factor
    normalise: normalisation of amplitudes to variance 1
    """
    from matplotlib.pyplot import subplots

    start = 0
    samples = data.shape[0]
    electrodes = data.shape[1]

    dataset = data[start:start+samples, :electrodes]
    means = data[start:start+samples, :electrodes].mean(axis=0)
    devs = data[start:start+samples, :electrodes].std(axis=0)

    fig, ax = subplots(figsize=(8, 6))

    if not normalise:
        ax.plot((dataset - means)      + offset*arange(electrodes-1,-1,-1),␣
↪linewidth=1);
```

```
    else:
        ax.plot((dataset - means)/devs + offset*arange(electrodes-1,-1,-1),␣
 ↪linewidth=1);

    ax.plot(zeros((samples, electrodes)) +␣
 ↪offset*arange(electrodes-1,-1,-1),'--',color='gray');
    ax.set(ylabel='Voltage')

    ax.set_yticklabels([]);

    return fig, ax
```

1.2 Pick Patient, Seizure, Type, and read EEG

[54]:
```
# read prefiltered 60 sec segment

folder      = '../Data/'
patient     = '1'          # '1'
seizure     = '03'         # '01' or '02' or '03'
series_type = 'Onset'      # 'Background' or 'Onset'

sr_chars = folder + 'sampling_rate.txt'

df1 = read_csv(sr_chars, header=None)

sr = df1.iloc[0, 0]

series_chars = folder + 'Pat' + patient + '_Sz' + seizure + '_' + series_type +␣
 ↪'_1_100Hz.csv'

df2 = read_csv(series_chars)
df2.head()

data_np = df2.to_numpy()
data_prefiltered = data_np[:, 1:]

all_labels = df2.columns[1:]

print('')
print(series_chars)
print('')
```

```
../Data/Pat1_Sz03_Onset_1_100Hz.csv
```

[55]:
```python
letter_list = list()

for new in all_labels:

    if new[0] not in letter_list:

        letter_list.append(new[0])


label_dict = dict()

for ind, letter in enumerate(all_labels):

    if letter[0] in label_dict.keys():
            pass

    else:
        label_dict[letter[0]] = [ind]

        dict_ind = len(label_dict.keys())

        if letter[0] != all_labels[0][0]:
            previous_letter = letter_list[dict_ind - 2]
            label_dict[previous_letter].append(ind)

    if ind == len(all_labels)-1:
        label_dict[letter[0]].append(ind+1)

label_letters = list(label_dict.keys())

label_dict
```

[55]:
```
{'A': [0, 11],
 'B': [11, 22],
 'C': [22, 31],
 'E': [31, 40],
 'F': [40, 49],
 'Z': [49, 56],
 'O': [56, 67],
 'T': [67, 74],
 'U': [74, 81],
 'V': [81, 92],
 'W': [92, 107],
 'X': [107, 122]}
```

[58]:
```python
all_labels[11:22]
```

[58]: Index(['B1-B2', 'B2-B3', 'B3-B4', 'B4-B5', 'B5-B6', 'B6-B7', 'B7-B8', 'B8-B9',
       'B9-B10', 'B10-B11', 'B11-B12'],
      dtype='object')

1.3 Settings and Filtering

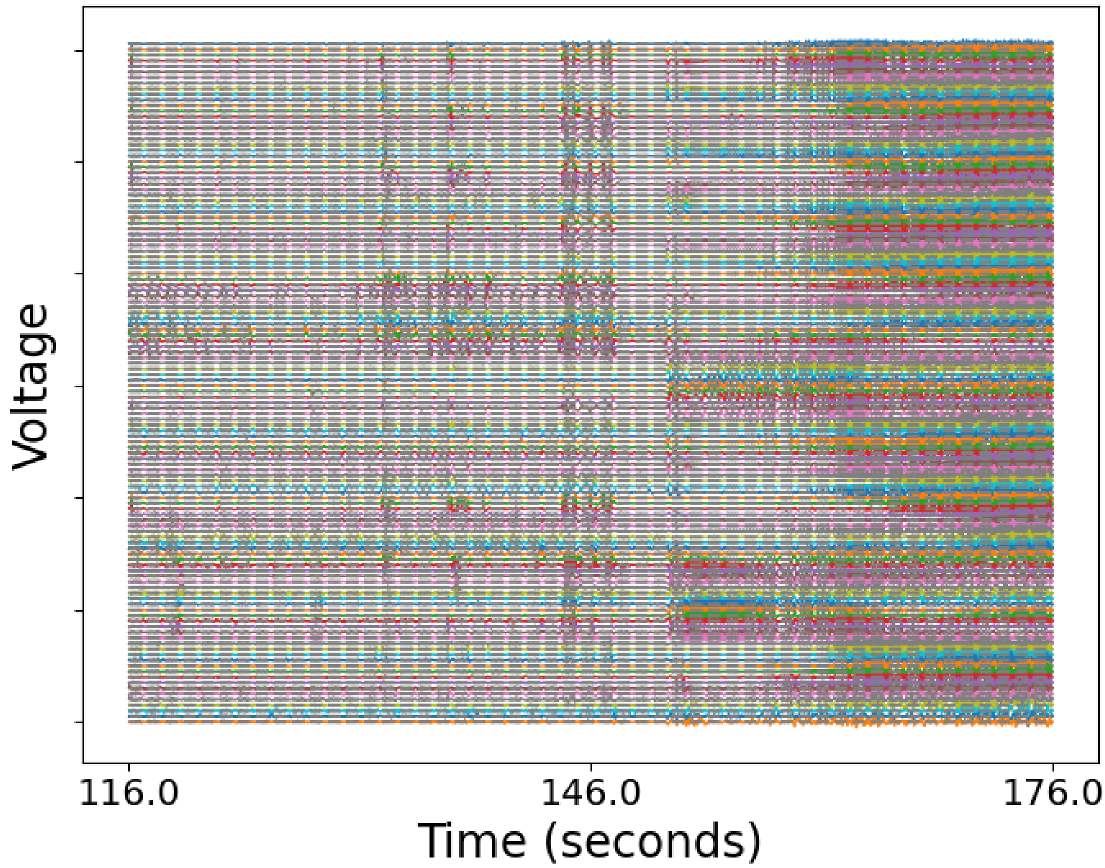
[61]:
```
onset  = (146.7, 147.0, 146.7)
```

[63]:
```
time_max = 60

init_cut  = 25

band_low  = 1
band_high = 20

order = 5

rows_max = int(time_max * sr)

sample_start = int((onset[int(seizure)-1]-30)*sr)
# sample_start = 0

sample_end = sample_start + rows_max

channel_start, channel_stop = 0, data_prefiltered.shape[1]  # Bad channels 81,␣
↪82 for 2015lvxiaofu

number_channels = channel_stop - channel_start


data_unfiltered = data_prefiltered[:, channel_start:channel_stop]


sos = butter(order, (band_low, band_high), btype='bandpass', fs=sr,␣
↪output='sos')

data_filtered = zeros((rows_max, number_channels))

for index, column in enumerate(data_unfiltered.transpose()):
    forward = sosfilt(sos, column)
    backwards = sosfilt(sos, forward[-1::-1])
    data_filtered[:, index] = backwards[-1::-1]

data_filtered.shape
```

[63]: (60000, 122)

2 Complete EEG

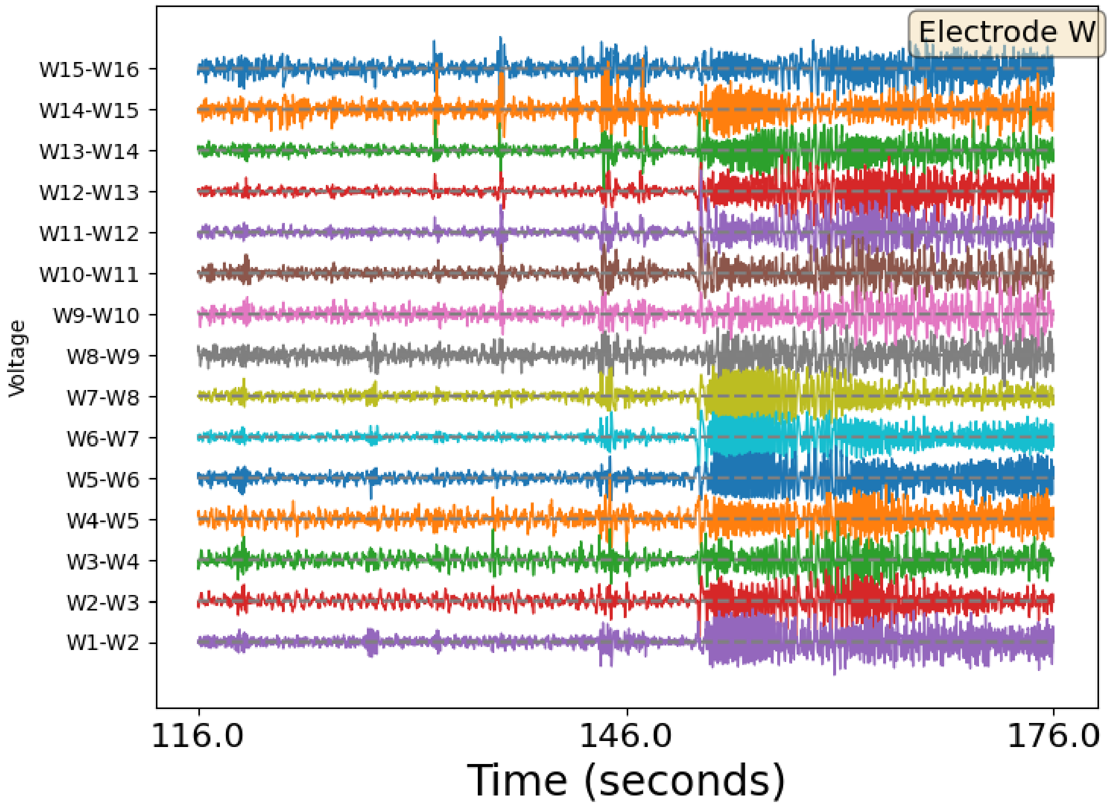
[66]:
```
fig, ax = eeg_plot(data_filtered, 5)

ax.set_xticks(linspace(0, rows_max, 3))
labl = linspace(sample_start//sr, sample_start//sr + time_max, 3)
ax.set_xticklabels(labl, fontsize=16)
ax.set_xlabel('Time (seconds)', fontsize=20)

ax.set_ylabel('Voltage', fontsize=20);
```



3 A Single Electrode

[68]:
```
elec_name = 'W'

all_labels_np = asarray(all_labels)
```

```
elec_label_names = all_labels_np[label_dict[elec_name][0]:
 ↪label_dict[elec_name][1]]

data_chan      = data_filtered[:, label_dict[elec_name][0]:
 ↪label_dict[elec_name][1]]

chans = data_chan.shape[1]

factor = 5

fig, ax = eeg_plot(data_chan, factor, normalise=True)
ax.set_yticks(factor*arange(chans))
ax.set_yticklabels(elec_label_names)

ax.set_xticks(linspace(0, rows_max, 3))
labl = linspace(sample_start//sr, sample_start//sr + time_max, 3)
ax.set_xticklabels(labl, fontsize=16)
ax.set_xlabel('Time (seconds)', fontsize=20)

# these are matplotlib.patch.Patch properties
props = dict(boxstyle='round', facecolor='wheat', alpha=0.5)

# place a text box in upper left in axes coords
textstr = 'Electrode ' + elec_name
ax.text(0.81, 0.98, textstr, transform=ax.transAxes, fontsize=14,
    verticalalignment='top', bbox=props);
```



[ ]:

```
```

3.1 Pick a Segment and Normalise

[73]:

```
seg_start = 20000
seg_stop  = 50000

rows_seg = seg_stop - seg_start

data_chan_seg      = data_chan[seg_start:seg_stop, :]

means              = data_chan_seg.mean(axis=0)
devs               = data_chan_seg.std(axis=0)
data_chan_seg_norm = (data_chan_seg - means)/devs
```

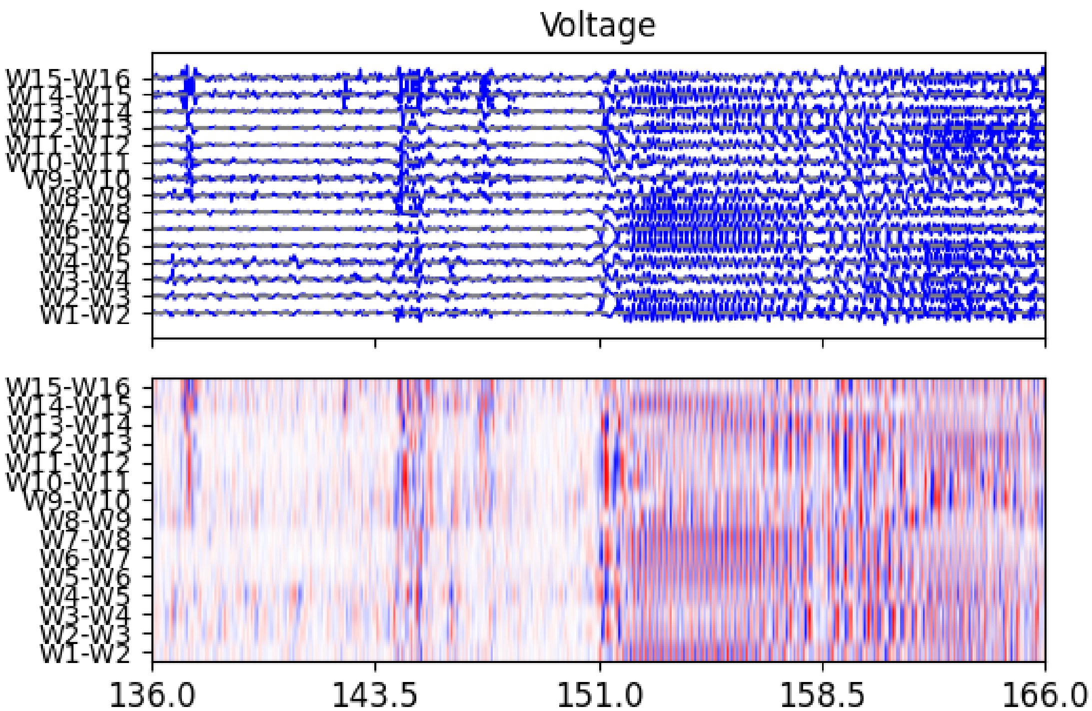
3.2 Time Series & Heatmap

[78]:

```
offset = 5

#################################### Time Series
fig, (ax1, ax2) = subplots(nrows=2, figsize=(6,4))
```

```python
### Voltage Series
ax1.plot(data_chan_seg_norm + offset*arange(chans-1,-1,-1), linewidth=1,␣
 ↪color='b');
ax1.plot(zeros((rows_seg, chans)) +␣
 ↪offset*arange(chans-1,-1,-1),'--',color='gray');
ax1.set_yticks(offset*arange(chans))
ax1.set_yticklabels(elec_label_names)
ax1.margins(x=0)
ax1.set_xticks(linspace(0, rows_seg, 5))
labl =        linspace((sample_start+seg_start)//sr, (sample_start+seg_stop)//
 ↪sr, 5)
ax1.set_xticklabels([], fontsize=12)
ax1.set_title('Voltage', fontsize=12)


### Voltage Heatmap
ax2.imshow(data_chan_seg_norm.T, aspect='auto', cmap='bwr', vmin=-3, vmax=3);
ax2.set_yticks(arange(chans))
ax2.set_yticklabels(flip(elec_label_names));

ax2.set_xticks(linspace(0, rows_seg, 5))
labl =        linspace((sample_start+seg_start)//sr, (sample_start+seg_stop)//
 ↪sr, 5)
ax2.set_xticklabels(labl, fontsize=12)


fig.tight_layout()

title_chars = 'figs/Sz' + seizure + '_' + elec_name + '_timeseries_' + 'L' +␣
 ↪str(band_low) + '_H' + str(band_high) + '_Start' + str(seg_start) + '.png'
# fig.savefig(title_chars, format='png')
print(title_chars)
```

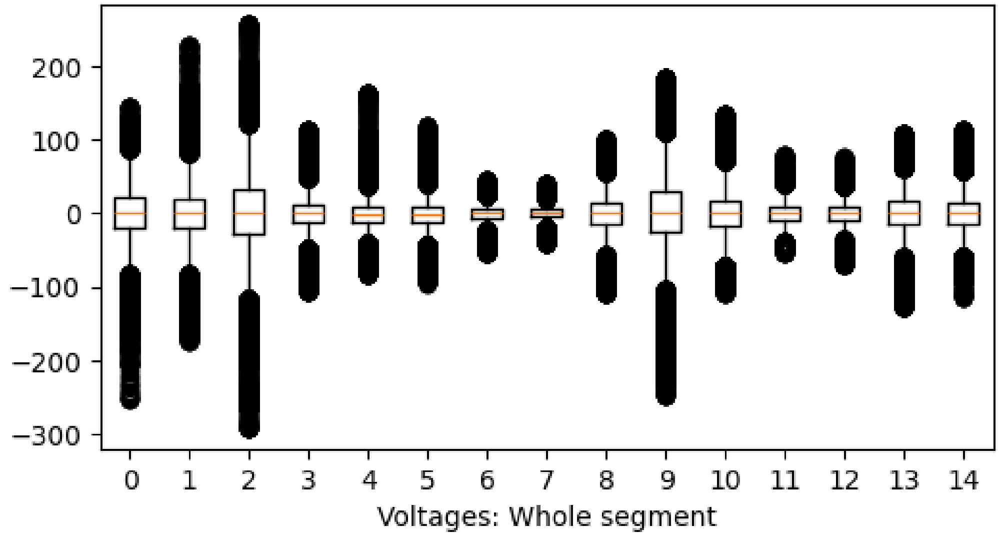
```
figs/Sz03_W_timeseries_L1_H20_Start20000.png
```



Electrode A: during the seizure too regular, too big, too synchronised.

3.3 Boxplots of Each Channel

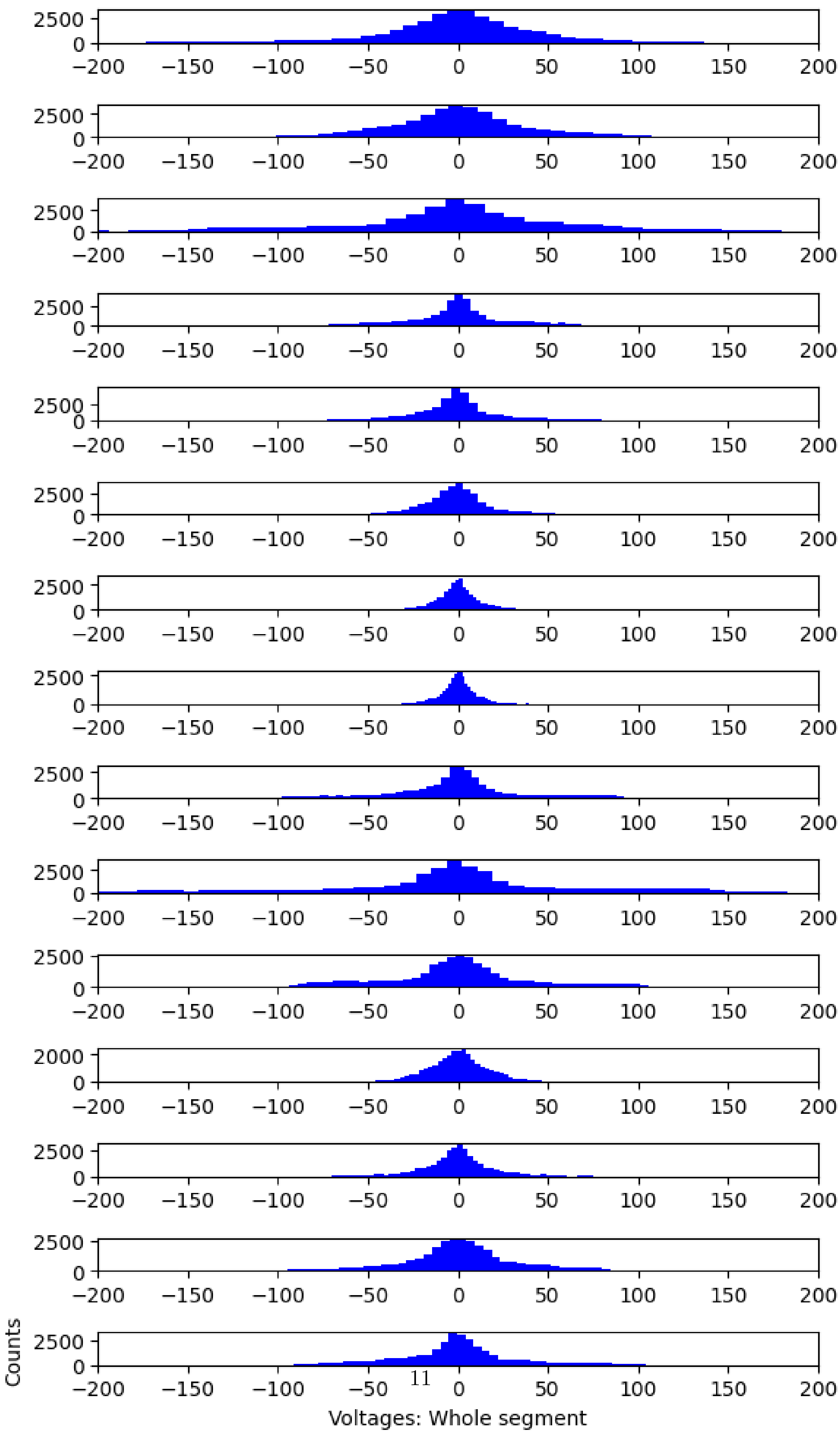
[84]:
```
fig, ax = subplots(figsize=(6,3))

ax.boxplot(data_chan_seg);
ax.set_xlabel('Voltages: Whole segment')
ax.set_xticklabels(arange(chans));
```



3.4 Histograms

[88]:

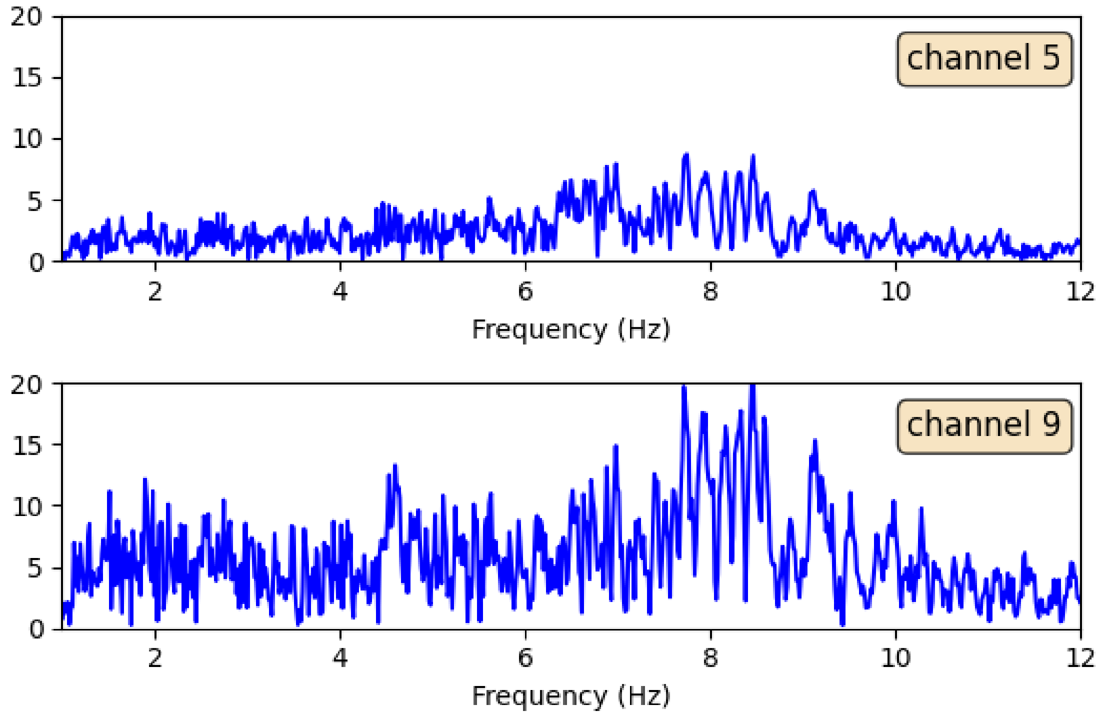
```
fig, ax = subplots(nrows=chans, figsize=(6,10))

bins = 50

for index in arange(chans):

    ax[index].hist(data_chan_seg[:,index], bins=bins, color='b');
    ax[index].set_xlim(-200, 200)

ax[-1].set_xlabel('Voltages: Whole segment')
ax[-1].set_ylabel('Counts');

fig.tight_layout()
```


2500
2000
0
−200
−150
−100
−50
0
50
100
150
200
Counts
Voltages: Whole segment

3.5 The Fourier Spectrum

[93]:

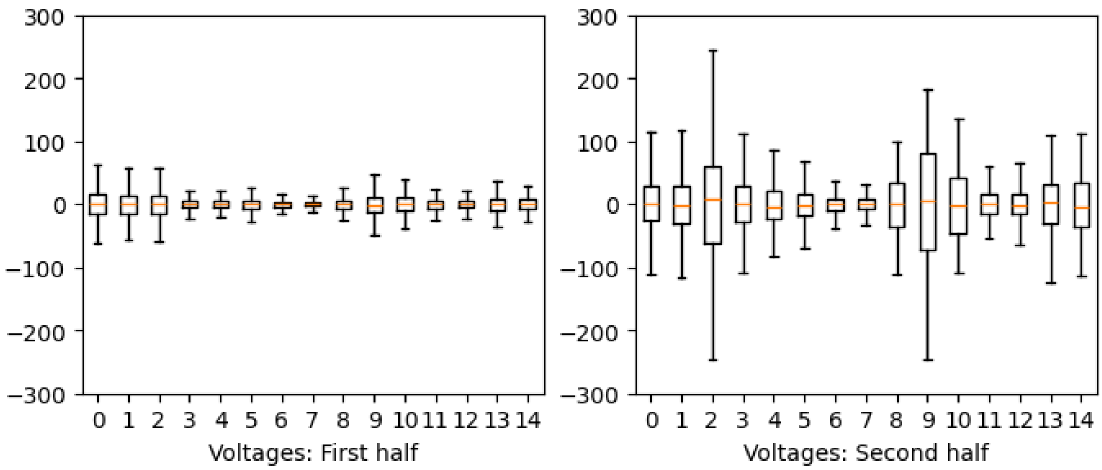
```
chan1, chan2 = 5, 9

ylim = 20

# frequencies
freqs = rfftfreq(rows_max, 1 / sr)

# amplitude
amplitudes = (2.0 / rows_max)*abs(rfft(data_filtered, axis=0))


fig, ax = subplots(nrows=2, figsize=(6, 4))

ax[0].plot(freqs, amplitudes[:, chan1], c='b');
ax[0].set_xlim(1, 12);
ax[0].set_ylim(0, ylim);
ax[0].set_xlabel('Frequency (Hz)');

ax[1].plot(freqs, amplitudes[:, chan2], c='b');
ax[1].set_xlim(1, 12);
ax[1].set_ylim(0, ylim);
ax[1].set_xlabel('Frequency (Hz)');

# these are matplotlib.patch.Patch properties
props = dict(boxstyle='round', facecolor='wheat', alpha=0.8)

# place a text box in upper left in axes coords
textstr = 'channel ' + str(chan1)

ax[0].text(0.83, 0.89, textstr, transform=ax[0].transAxes, fontsize=12,
    verticalalignment='top', bbox=props)

textstr = 'channel ' + str(chan2)

ax[1].text(0.83, 0.89, textstr, transform=ax[1].transAxes, fontsize=12,
    verticalalignment='top', bbox=props)

fig.tight_layout()
```



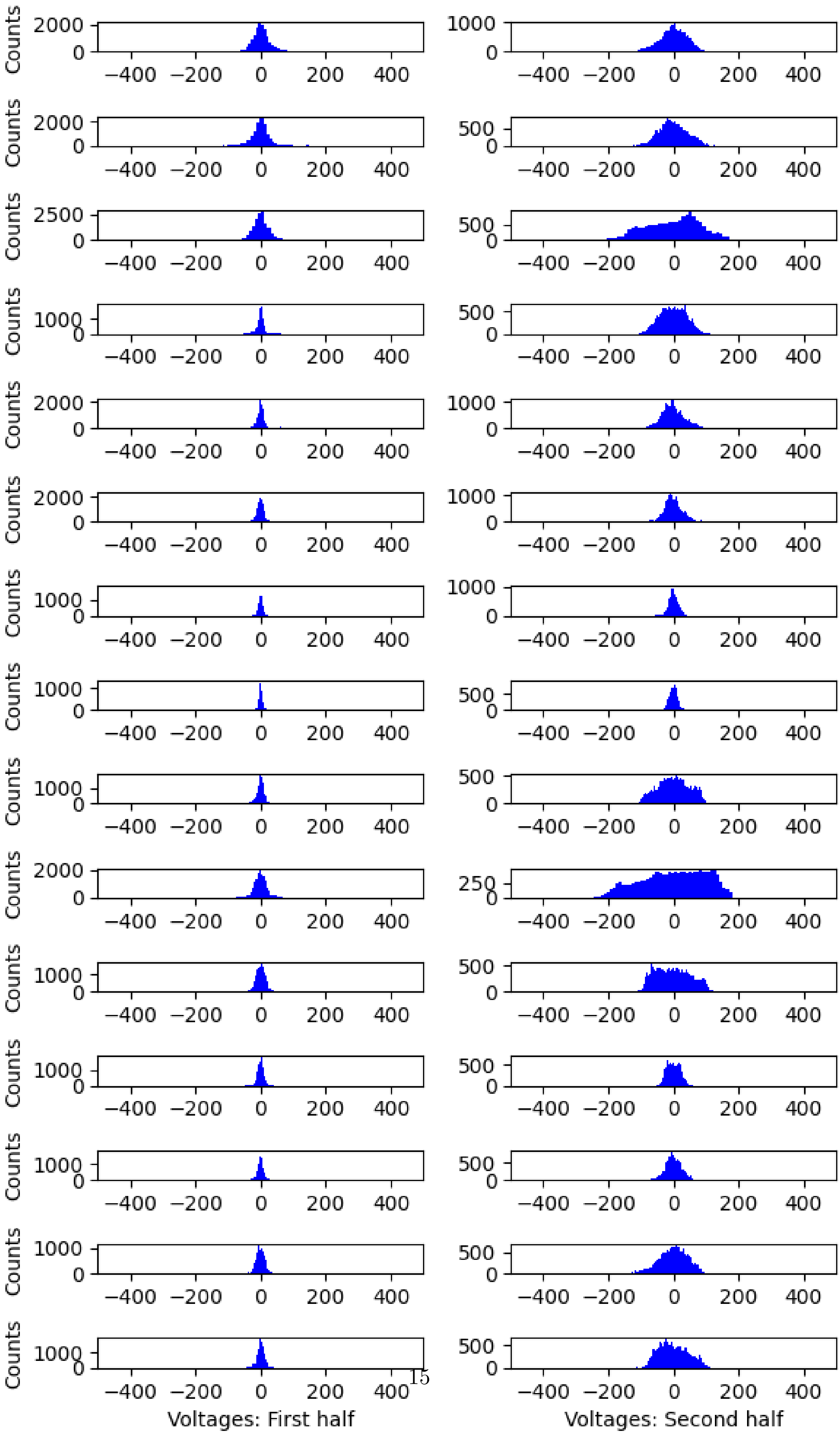

```
[ ]:
```

3.6 Boxplots & Histograms of Half Segments

```
[95]: limit = 300

fig, ax = subplots(ncols=2, figsize=(8,3))

ax[0].boxplot(data_chan_seg[:rows_seg//2,:], showfliers=False);
ax[0].set_xticklabels(arange(chans))
ax[0].set_ylim(-limit, limit)

ax[0].set_xlabel('Voltages: First half')

ax[1].boxplot(data_chan_seg[rows_seg//2:,:], showfliers=False);
ax[1].set_xticklabels(arange(chans))
ax[1].set_ylim(-limit, limit)

ax[1].set_xlabel('Voltages: Second half');
```

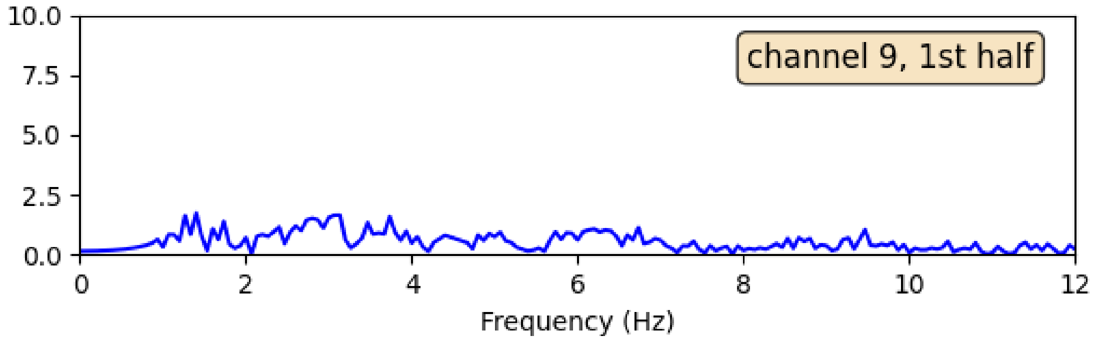


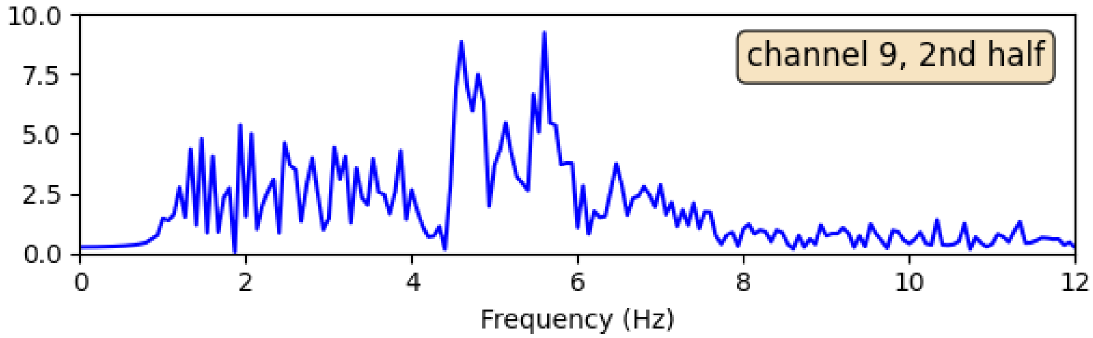
[99]:
```
fig, ax = subplots(nrows=chans, ncols=2, figsize=(6,10))

for index in arange(chans):

    ax[index, 0].hist(data_chan_seg[:rows_seg//2,index], bins=bins, color='b');
    ax[index, 0].set_ylabel('Counts');
    ax[index, 1].hist(data_chan_seg[rows_seg//2:,index], bins=bins, color='b');
    ax[index, 0].set_xlim(-500, 500)
    ax[index, 1].set_xlim(-500, 500)

ax[-1, 0].set_xlabel('Voltages: First half')
ax[-1, 1].set_xlabel('Voltages: Second half')

fig.tight_layout()
```


Counts
Voltages: First half
Voltages: Second half

3.7 Fourier spectra of half segments

[104]:
```
chan = 9

ylim = 10

# frequencies
freqs = rfftfreq(rows_seg//2, 1 / sr)

# amplitude
amplitudes_1 = (2.0 / rows_max)*abs(rfft(data_chan_seg[:rows_seg//2, :],␣
↪axis=0))
amplitudes_2 = (2.0 / rows_max)*abs(rfft(data_chan_seg[rows_seg//2:, :],␣
↪axis=0))



fig, ax = subplots(nrows=2, figsize=(6, 4))

ax[0].plot(freqs, amplitudes_1[:, chan], color='b');
ax[0].set_xlim(0, 12);
ax[0].set_ylim(0, ylim);
ax[0].set_xlabel('Frequency (Hz)');

ax[1].plot(freqs, amplitudes_2[:, chan], color='b');
ax[1].set_xlim(0, 12);
ax[1].set_ylim(0, ylim);
ax[1].set_xlabel('Frequency (Hz)');

# these are matplotlib.patch.Patch properties
props = dict(boxstyle='round', facecolor='wheat', alpha=0.8)

# place a text box in upper left in axes coords
textstr = 'channel ' + str(chan) + ', 1st half'

ax[0].text(0.67, 0.89, textstr, transform=ax[0].transAxes, fontsize=12,
    verticalalignment='top', bbox=props)

textstr = 'channel ' + str(chan) + ', 2nd half'

ax[1].text(0.67, 0.89, textstr, transform=ax[1].transAxes, fontsize=12,
    verticalalignment='top', bbox=props)

fig.tight_layout()
```





4 Summary

- EEG is integral over extracellular currents in complex brain tissue (neurons, glia, blood vessels)
- EEG is organised in spatio-temporal patterns
- Normal Dynamics: irregular in frequency; small in amplitude; non-specific waveform
- Epileptic Dynamics: more regular frequency; often large amplitude; charactersitic waveforms.

5 Try It Yourself

Display data from different electrodes and pick different segments to re-run the code. You will be able to find segments with strongly contrasting types of dynamics. If you achieve to adjust the half segments, you will be able to maimise the contrast in univariate measures.

[ ]:

```

```