Removing muscle ICA components

Gross movements produce widespread high-frequency activity across all channels that is usually not recoverable and so the epoch must be rejected as shown in `ex-muscle-artifacts`. More ubiquitously than gross movements, muscle artifact is produced during postural maintenance. This is more appropriately removed by ICA otherwise there wouldn't be any epochs left! Note that muscle artifacts of this kind are much more pronounced in EEG than they are in MEG.

```
# Authors: Alex Rockhill <aprockhill@mailbox.org>
#
# License: BSD-3-Clause
# Copyright the MNE-Python contributors.


import mne

data_path = mne.datasets.sample.data_path()
raw_fname = data_path / "MEG" / "sample" / "sample_audvis_raw.fif"
raw = mne.io.read_raw_fif(raw_fname)
raw.crop(tmin=100, tmax=130)  # take 30 seconds for speed

# pick only EEG channels, muscle artifact is basically not picked up by MEG
# if you have a simultaneous recording, you may want to do ICA on MEG and EEG
# separately
raw.pick(picks="eeg", exclude="bads")

# ICA works best with a highpass filter applied
raw.load_data()
raw.filter(l_freq=1.0, h_freq=None)
```

```
Opening raw data file C:\Users\ulewi\mne_data\MNE-sample-data\MEG\sample\sample_audvis_raw.fif...
    Read a total of 3 projection items:
        PCA-v1 (1 x 102)  idle
        PCA-v2 (1 x 102)  idle
        PCA-v3 (1 x 102)  idle
    Range : 25800 ... 192599 =     42.956 ...   320.670 secs
Ready.
Reading 0 ... 18019  =      0.000 ...    30.001 secs...
Filtering raw data in 1 contiguous segment
Setting up high-pass filter at 1 Hz

FIR filter parameters
---------------------
Designing a one-pass, zero-phase, non-causal highpass filter:
- Windowed time-domain design (firwin) method
- Hamming window with 0.0194 passband ripple and 53 dB stopband attenuation
- Lower passband edge: 1.00
- Lower transition bandwidth: 1.00 Hz (-6 dB cutoff frequency: 0.50 Hz)
- Filter length: 1983 samples (3.302 s)

[Parallel(n_jobs=1)]: Done  17 tasks      | elapsed:    0.0s
```

▼ **General**

Measurement date	December 03, 2002 19:01:10 GMT
Experimenter	MEG
Participant	Unknown

▼ **Channels**

Digitized points	146 points
Good channels	59 EEG
Bad channels	None
EOG channels	Not available
ECG channels	Not available

▼ **Data**

Sampling frequency	600.61 Hz
Highpass	1.00 Hz
Lowpass	172.18 Hz
Filenames	sample_audvis_raw.fif
Duration	00:00:31 (HH:MM:SS)

Run ICA

```
ica = mne.preprocessing.ICA(
    n_components=15, method="picard", max_iter="auto", random_state=97
)
ica.fit(raw)
```

```
Fitting ICA to data using 59 channels (please be patient, this may take a while)
Selecting by number: 15 components
Fitting ICA took 3.6s.
```

Method	picard
Fit parameters	max_iter=500
Fit	36 iterations on raw data (18020 samples)
ICA components	15
Available PCA components	59
Channel types	eeg
ICA components marked for exclusion	—

Remove components with postural muscle artifact using ICA

```
ica.plot_sources(raw)
```

```
Creating RawArray with float64 data, n_channels=15, n_times=9760
    Range : 0 ... 9759 =      0.000 ...    60.994 secs
Ready.
<mne_qt_browser._pg_figure.MNEQtBrowser at 0x1bf657a0f80>
```

By inspection, let's select out the muscle-artifact components based on :footcite: `DharmapraniEtAl2016` manually.

The criteria are:

- Positive slope of log-log power spectrum between 7 and 75 Hz (here just flat because it's not in log-log)
- Peripheral focus or dipole/multi-pole foci (the blue and red blobs in the topomap are far from the vertex where the most muscle is)
- Single focal point (low spatial smoothness; there is just one focus of the topomap compared to components like the first ones that are more likely neural which spread across the topomap)

The other attribute worth noting is that the time course in :func: `mne.preprocessing.ICA.plot_sources` looks like EMG; you can see spikes when each motor unit fires so that the time course looks fuzzy and sometimes has large spikes that are often at regular intervals.

ICA component 13 is a textbook example of what muscle artifact looks like. The focus of the topomap for this component is right on the temporalis muscle near the ears. There is also a minimum in the power spectrum at around 10 Hz, then a maximum at around 25 Hz, generally resulting in a positive slope in log-log units; this is a very typical pattern for muscle artifact.

```
idx = [0, 1, 2, 3, 4, 5, 6, 7]
ica.plot_properties(raw, picks=idx, log_scale=True)
```

```
    Using multitaper spectrum estimation with 7 DPSS windows
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
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30 matching events found
No baseline correction applied
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30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
c:\Users\ulewi\mne-python\1.7.0_0\Lib\site-packages\IPython\core\pylabtools.py:152: U
  fig.canvas.print_figure(bytes_io, **kw)
```
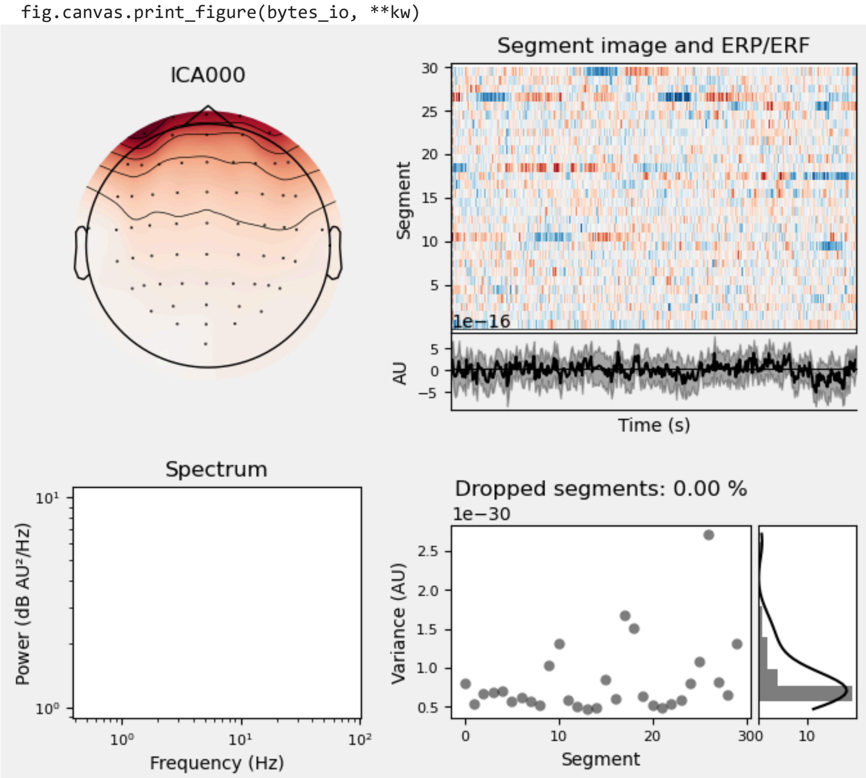
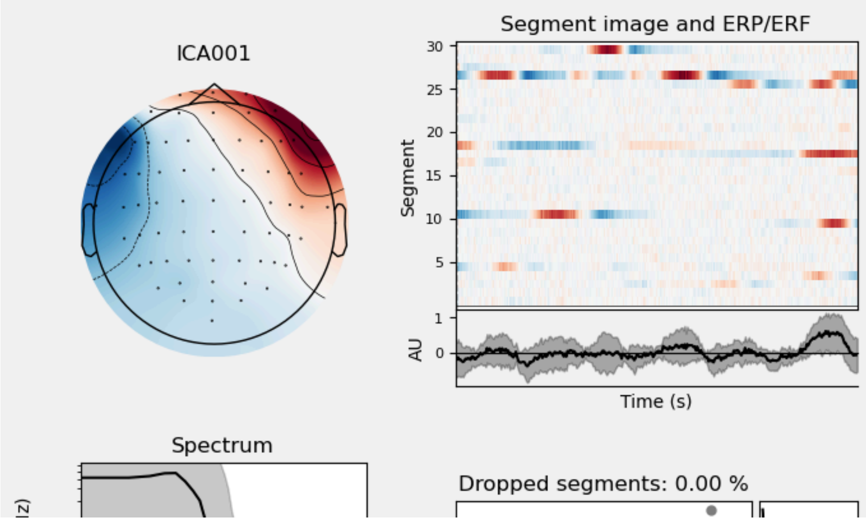
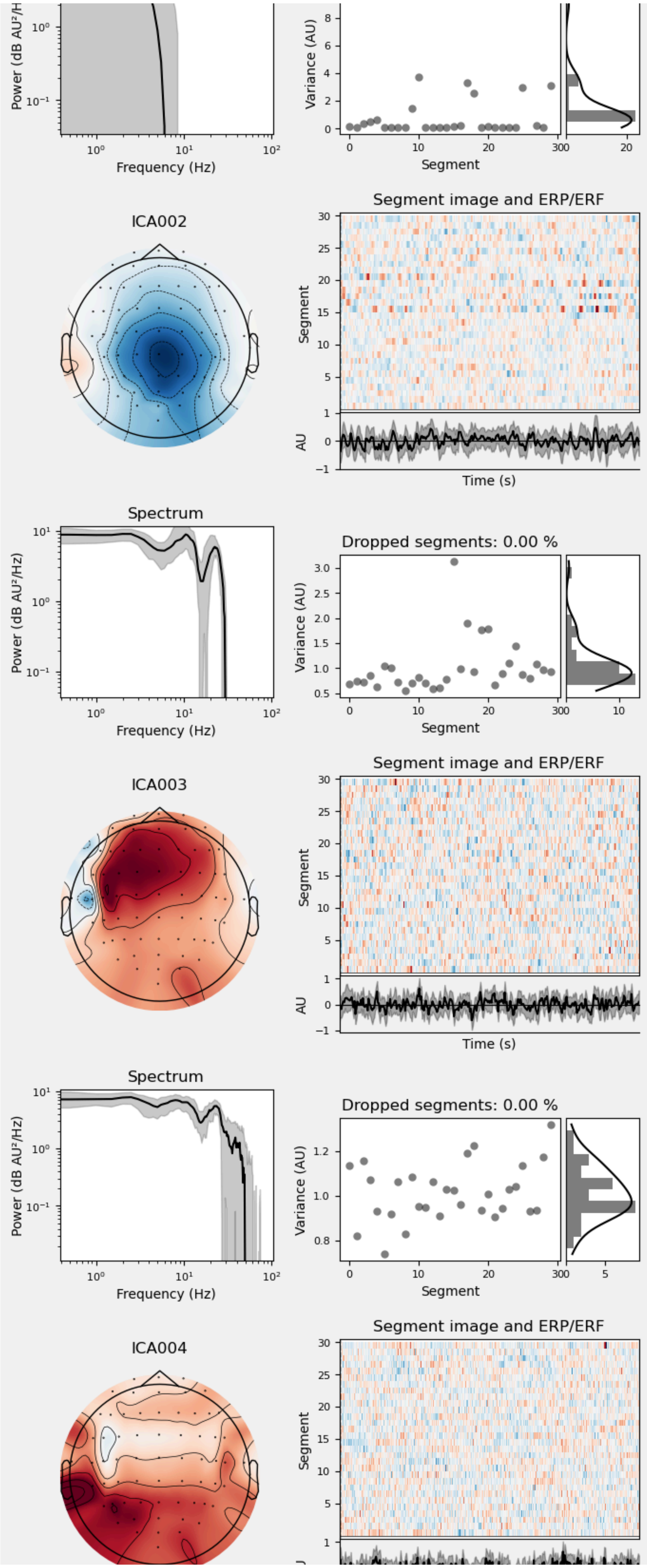
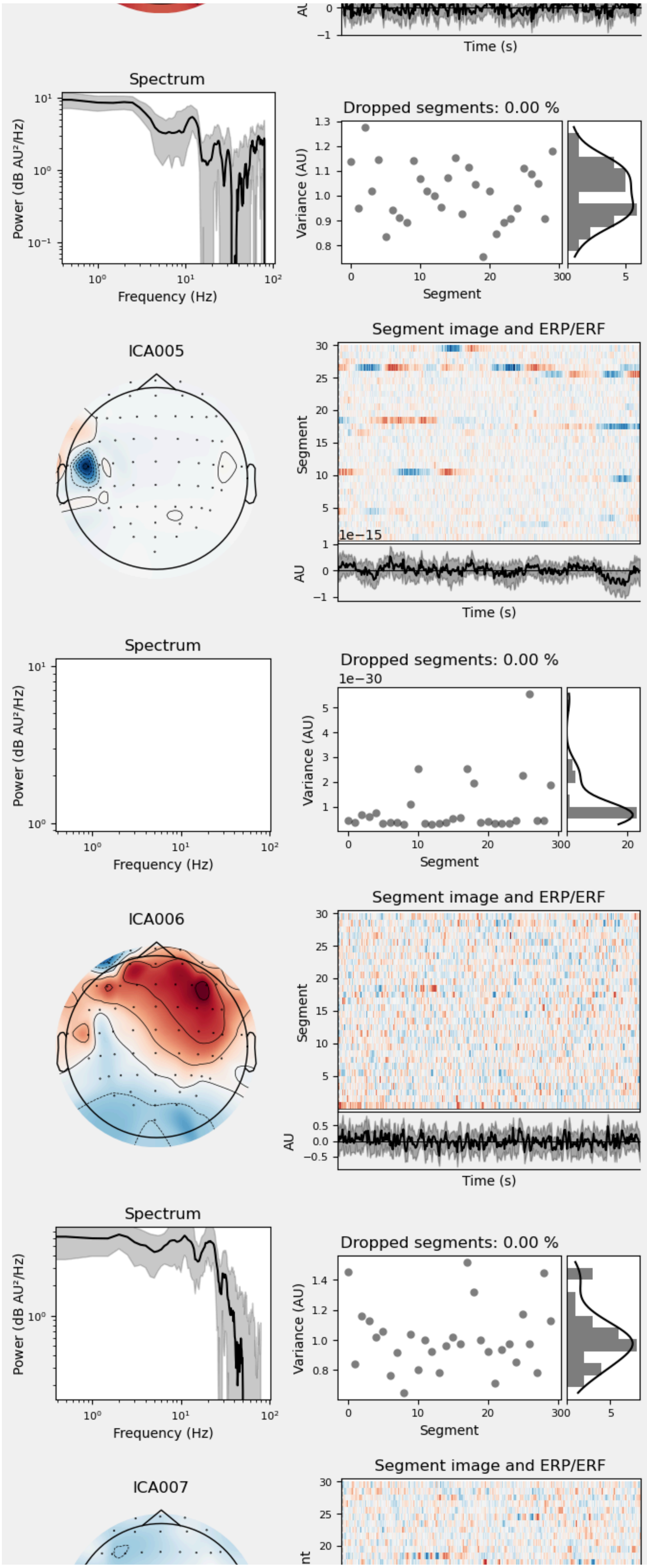
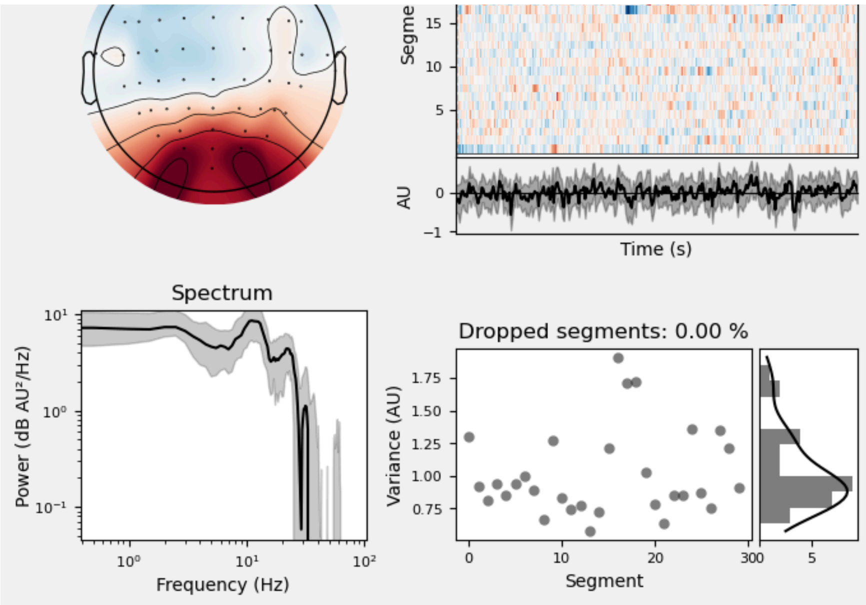






Power (dB AU²/Hz)
Frequency (Hz)
Variance (AU)
Segment
ICA002
Segment image and ERP/ERF
Segment
AU
Time (s)
Spectrum
Power (dB AU²/Hz)
Frequency (Hz)
Dropped segments: 0.00 %
Variance (AU)
Segment
ICA003
Segment image and ERP/ERF
Segment
AU
Time (s)
Spectrum
Power (dB AU²/Hz)
Frequency (Hz)
Dropped segments: 0.00 %
Variance (AU)
Segment
ICA004
Segment image and ERP/ERF
Segment


Time (s)
Spectrum
Power (dB AU²/Hz)
Frequency (Hz)
Dropped segments: 0.00 %
Variance (AU)
Segment
Segment image and ERP/ERF
ICA005
1e−15
AU
Time (s)
Spectrum
Power (dB AU²/Hz)
Frequency (Hz)
Dropped segments: 0.00 %
1e−30
Variance (AU)
Segment
Segment image and ERP/ERF
ICA006
AU
Time (s)
Spectrum
Power (dB AU²/Hz)
Frequency (Hz)
Dropped segments: 0.00 %
Variance (AU)
Segment
Segment image and ERP/ERF
ICA007




```
[<Figure size 700x600 with 6 Axes>,
 <Figure size 700x600 with 6 Axes>,
 <Figure size 700x600 with 6 Axes>,
 <Figure size 700x600 with 6 Axes>,
 <Figure size 700x600 with 6 Axes>,
 <Figure size 700x600 with 6 Axes>,
 <Figure size 700x600 with 6 Axes>,
 <Figure size 700x600 with 6 Axes>]
```

```
muscle_idx = [6, 7, 8, 9, 10, 11, 12, 13, 14]
ica.plot_properties(raw, picks=muscle_idx, log_scale=True)

# first, remove blinks and heartbeat to compare
blink_idx = [0]
heartbeat_idx = [5]
ica.apply(raw, exclude=blink_idx + heartbeat_idx)
ica.plot_overlay(raw, exclude=muscle_idx)
```

```
    Using multitaper spectrum estimation with 7 DPSS windows
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
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No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
```
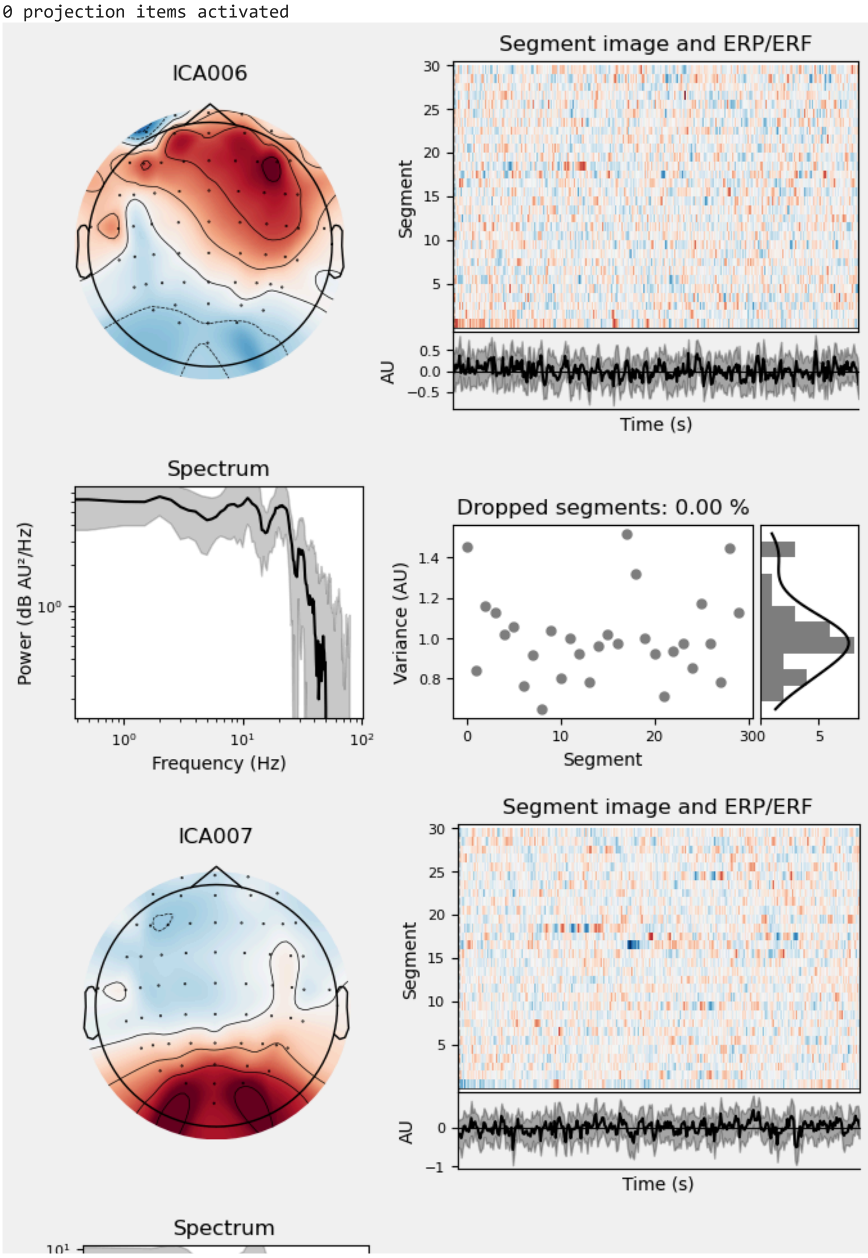
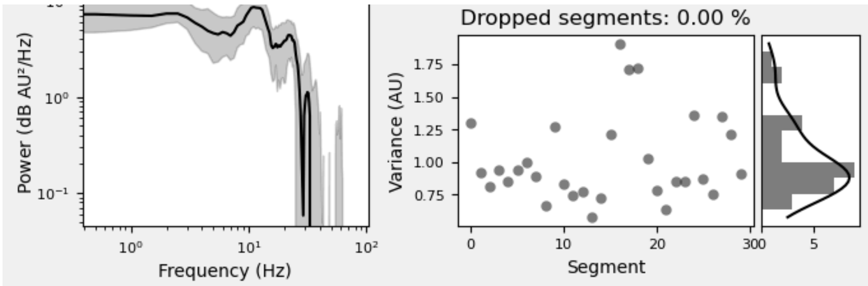
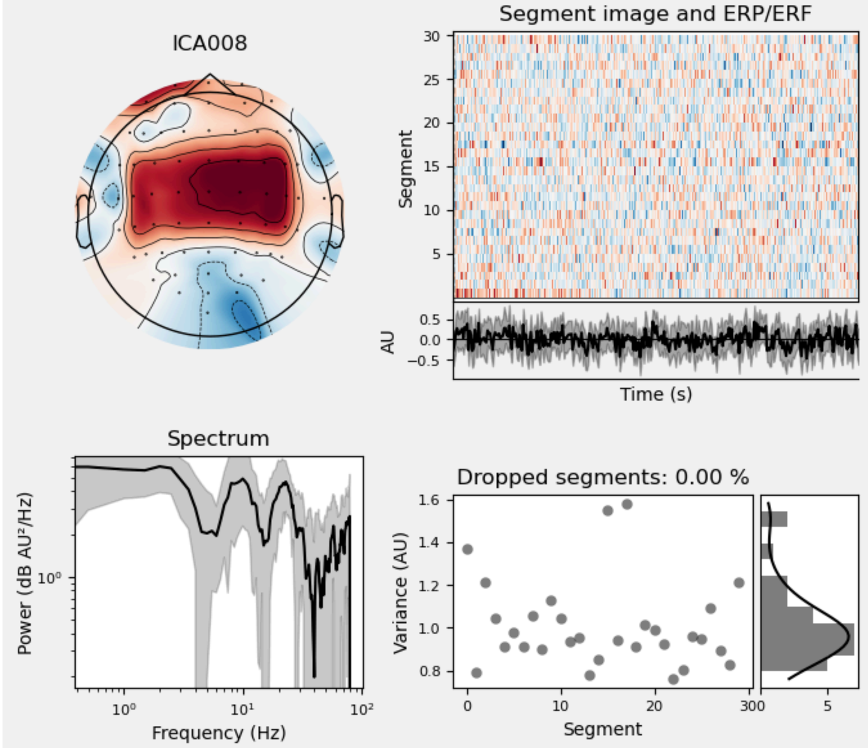
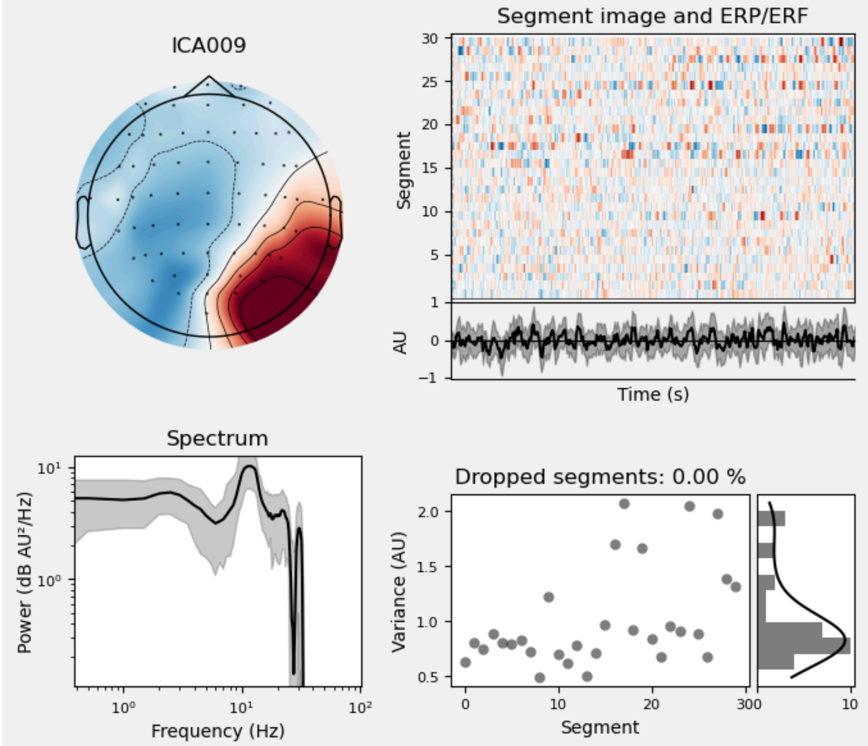
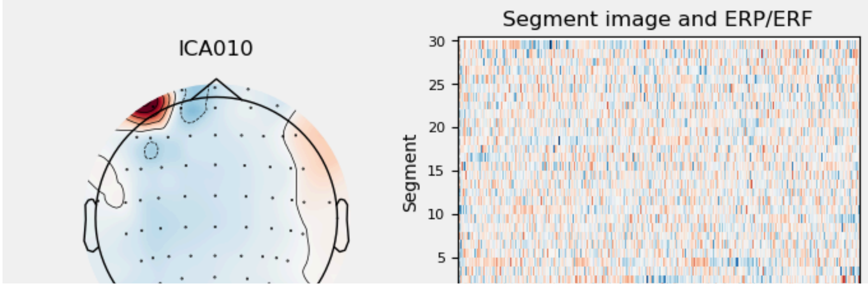
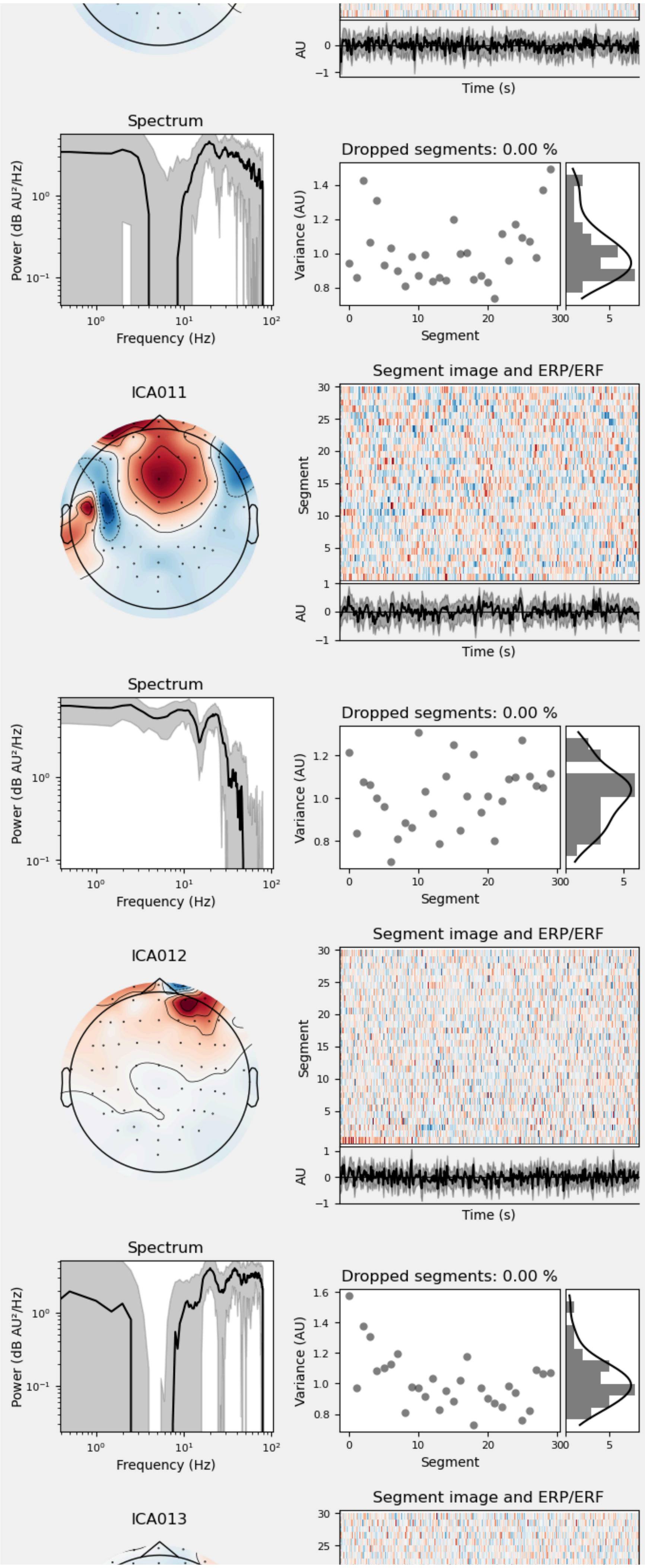



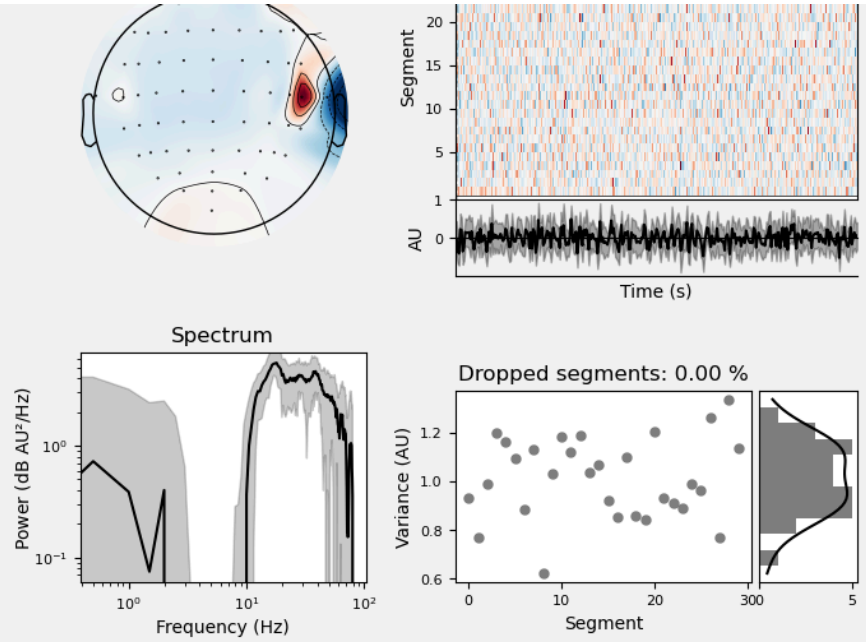

Power (dB AU²/Hz)
Frequency (Hz)
Dropped segments: 0.00 %
Variance (AU)
Segment

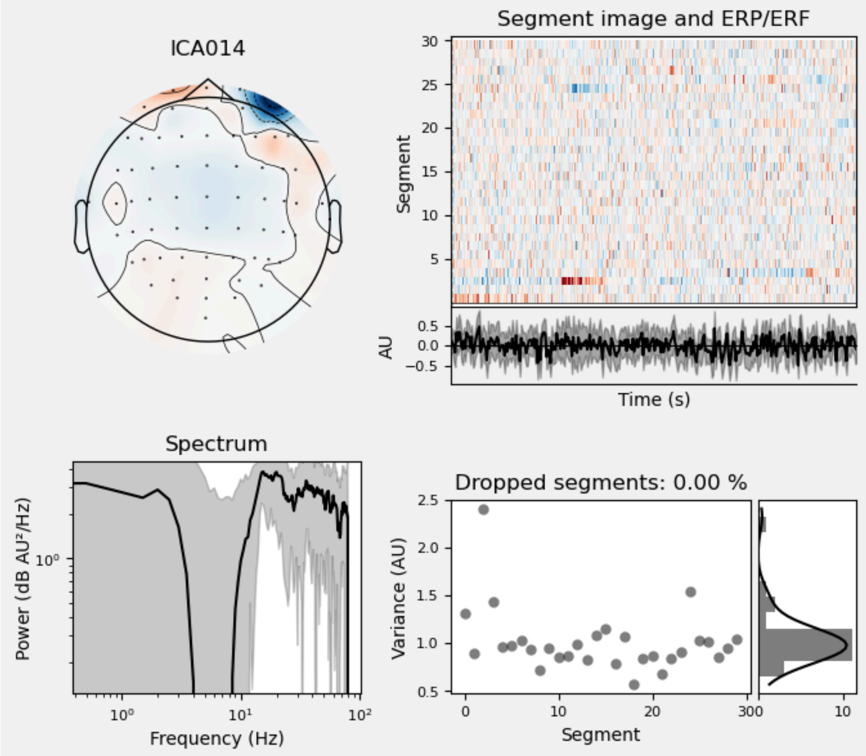

ICA008
Segment image and ERP/ERF
Segment
AU
Time (s)
Spectrum
Power (dB AU²/Hz)
Frequency (Hz)
Dropped segments: 0.00 %
Variance (AU)
Segment


ICA009
Segment image and ERP/ERF
Segment
AU
Time (s)
Spectrum
Power (dB AU²/Hz)
Frequency (Hz)
Dropped segments: 0.00 %
Variance (AU)
Segment

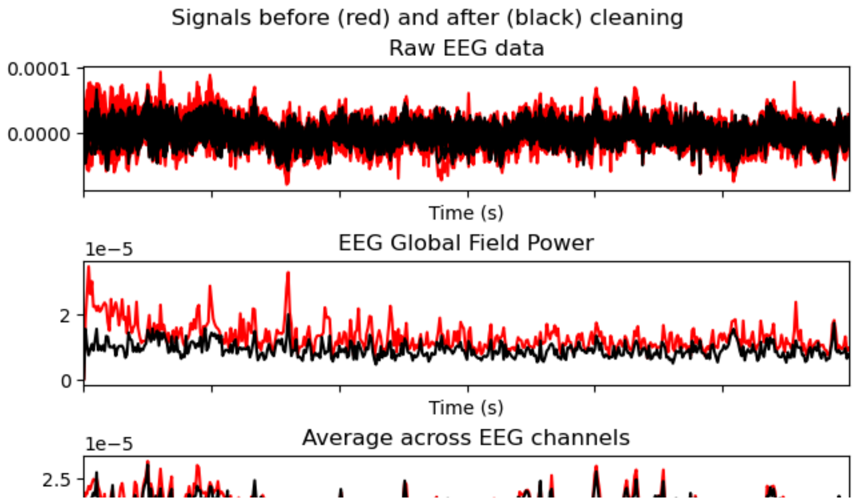

ICA010
Segment image and ERP/ERF
Segment

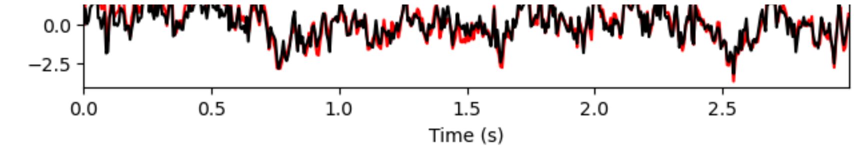

AU
Time (s)
Spectrum
Power (dB AU²/Hz)
Frequency (Hz)
Dropped segments: 0.00 %
Variance (AU)
Segment
Segment image and ERP/ERF
ICA011
Segment
AU
Time (s)
Spectrum
Power (dB AU²/Hz)
Frequency (Hz)
Dropped segments: 0.00 %
Variance (AU)
Segment
Segment image and ERP/ERF
ICA012
Segment
AU
Time (s)
Spectrum
Power (dB AU²/Hz)
Frequency (Hz)
Dropped segments: 0.00 %
Variance (AU)
Segment
Segment image and ERP/ERF
ICA013

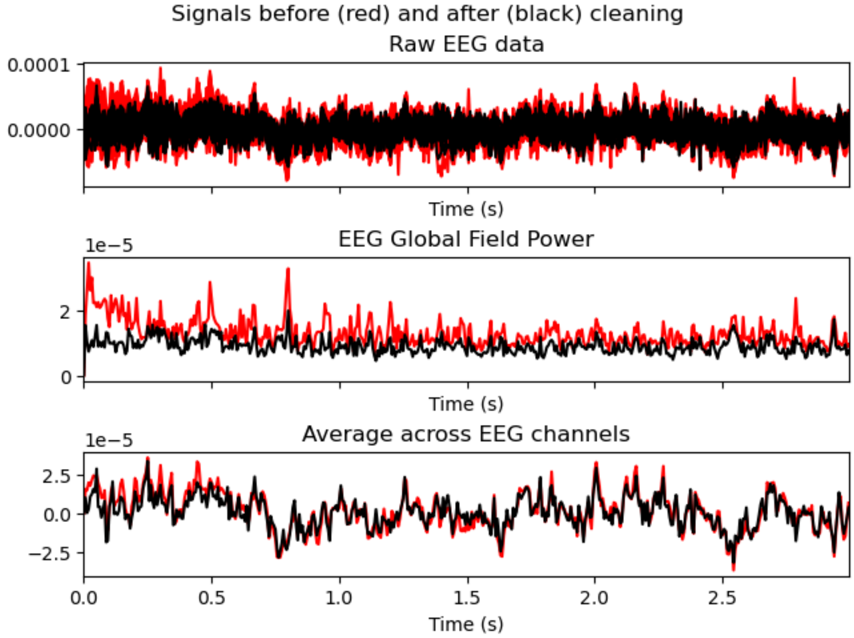





```
Applying ICA to Raw instance
    Transforming to ICA space (15 components)
    Zeroing out 2 ICA components
    Projecting back using 64 PCA components
Applying ICA to Raw instance
    Transforming to ICA space (15 components)
    Zeroing out 9 ICA components
    Projecting back using 64 PCA components
```



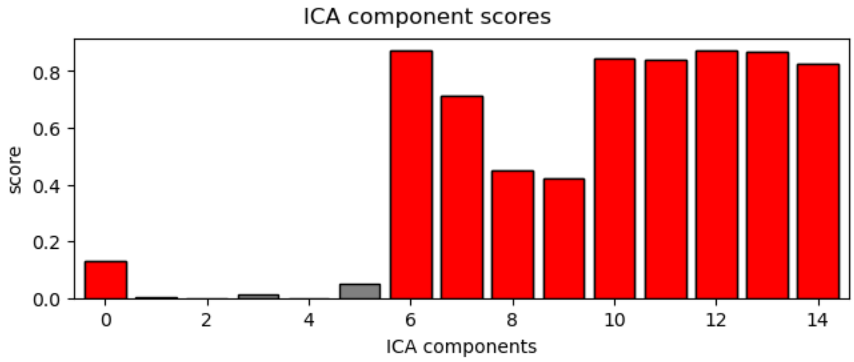




Finally, let's try an automated algorithm to find muscle components and ensure that it gets the same components we did manually.

```
muscle_idx_auto, scores = ica.find_bads_muscle(raw)
ica.plot_scores(scores, exclude=muscle_idx_auto)
print(
    f"Manually found muscle artifact ICA components:      {muscle_idx}\n"
    f"Automatically found muscle artifact ICA components: {muscle_idx_auto}"
)
```

```
Effective window size : 3.410 (s)
```

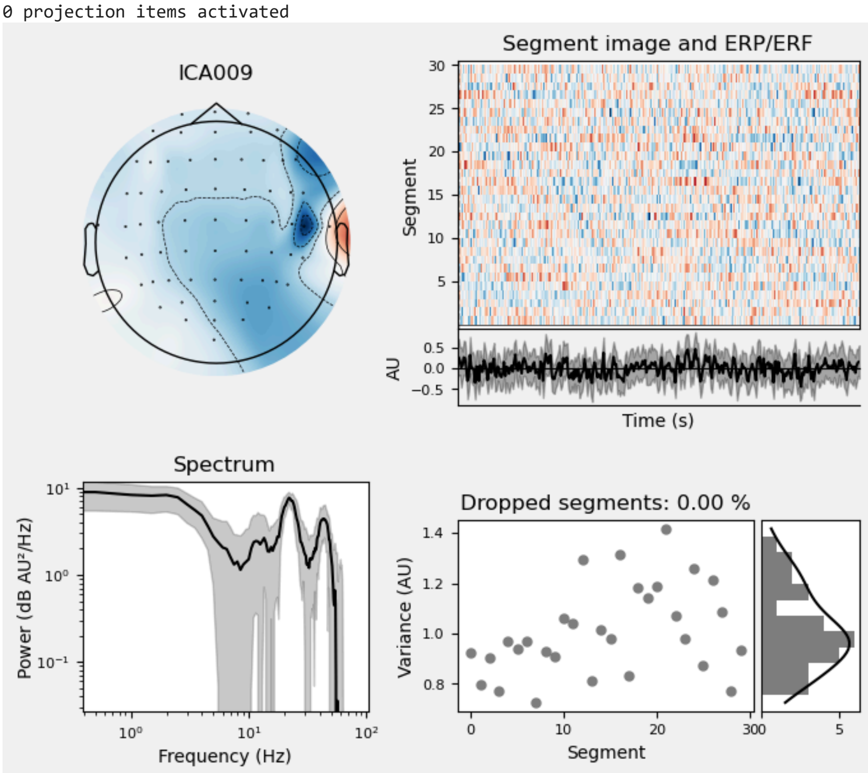


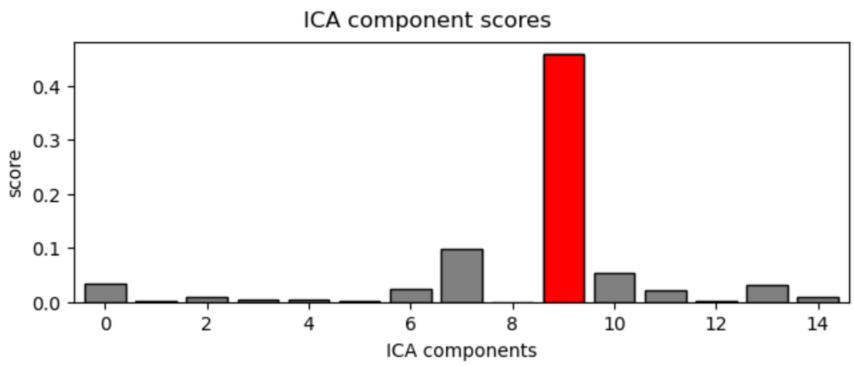

```
Manually found muscle artifact ICA components:      [6, 7, 8, 9, 10, 11, 12, 13, 14]
Automatically found muscle artifact ICA components: [0, 6, 7, 8, 9, 10, 11, 12, 13, 1
```

Let's now replicate this on the EEGBCI dataset

```
for sub in (1, 2):
    raw = mne.io.read_raw_edf(
        mne.datasets.eegbci.load_data(subject=sub, runs=(1,))[0], preload=True
    )
    mne.datasets.eegbci.standardize(raw)  # set channel names
    montage = mne.channels.make_standard_montage("standard_1005")
    raw.set_montage(montage)
    raw.filter(l_freq=1.0, h_freq=None)

    # Run ICA
    ica = mne.preprocessing.ICA(
        n_components=15, method="picard", max_iter="auto", random_state=97
    )
    ica.fit(raw)
    ica.plot_sources(raw)
    muscle_idx_auto, scores = ica.find_bads_muscle(raw)
    ica.plot_properties(raw, picks=muscle_idx_auto, log_scale=True)
    ica.plot_scores(scores, exclude=muscle_idx_auto)

    print(
        f"Manually found muscle artifact ICA components:      {muscle_idx}\n"
        "Automatically found muscle artifact ICA components: "
        f"{muscle_idx_auto}"
    )
```

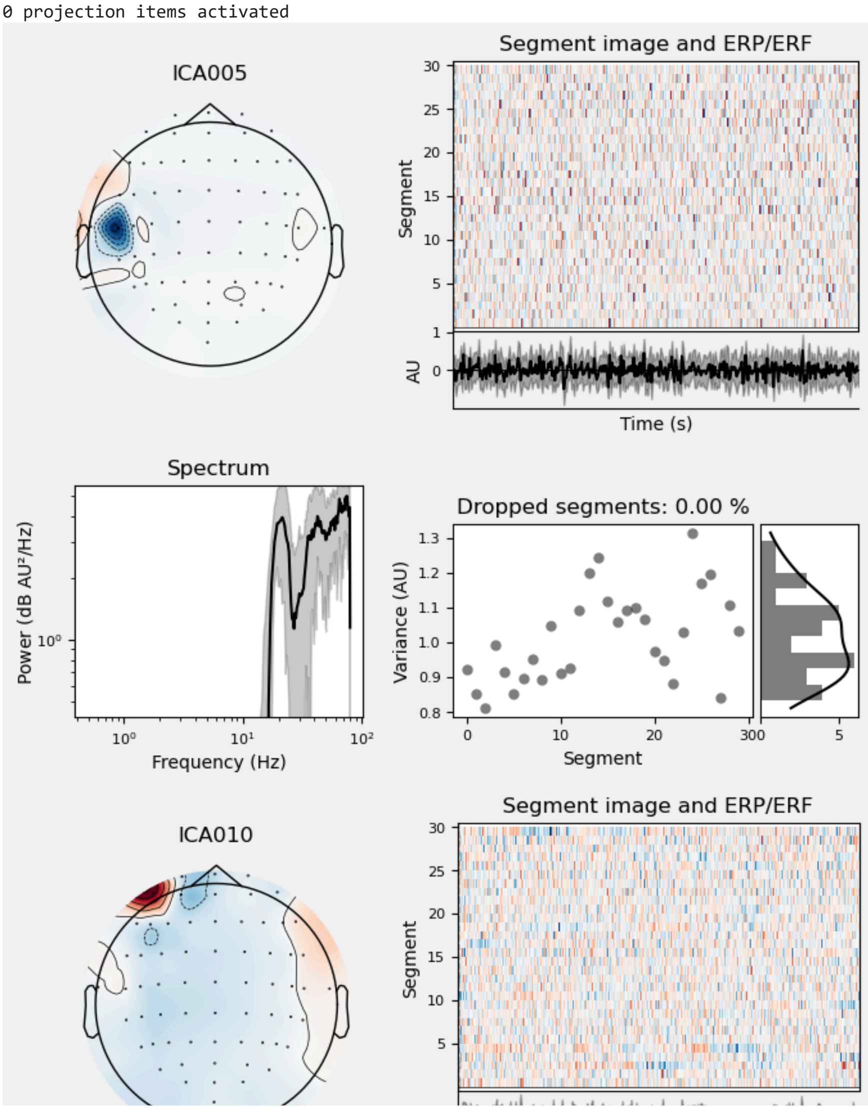
```
Using default location ~/mne_data for EEGBCI...
Downloading EEGBCI data
Downloading file 'S001/S001R01.edf' from 'https://physionet.org/files/eegmmidb/1.0.0/
Download complete in 26s (1.2 MB)
Extracting EDF parameters from C:\Users\ulewi\mne_data\MNE-eegbci-data\files\eegmmidb
EDF file detected
Setting channel info structure...
Creating raw.info structure...
Reading 0 ... 9759  =      0.000 ...    60.994 secs...
Filtering raw data in 1 contiguous segment
Setting up high-pass filter at 1 Hz

FIR filter parameters
---------------------
Designing a one-pass, zero-phase, non-causal highpass filter:
- Windowed time-domain design (firwin) method
- Hamming window with 0.0194 passband ripple and 53 dB stopband attenuation
- Lower passband edge: 1.00
- Lower transition bandwidth: 1.00 Hz (-6 dB cutoff frequency: 0.50 Hz)
- Filter length: 529 samples (3.306 s)

Fitting ICA to data using 64 channels (please be patient, this may take a while)
[Parallel(n_jobs=1)]: Done  17 tasks      | elapsed:    0.0s
Selecting by number: 15 components
Fitting ICA took 2.2s.
Creating RawArray with float64 data, n_channels=15, n_times=9760
    Range : 0 ... 9759 =      0.000 ...    60.994 secs
Ready.
Effective window size : 12.800 (s)
    Using multitaper spectrum estimation with 7 DPSS windows
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
```

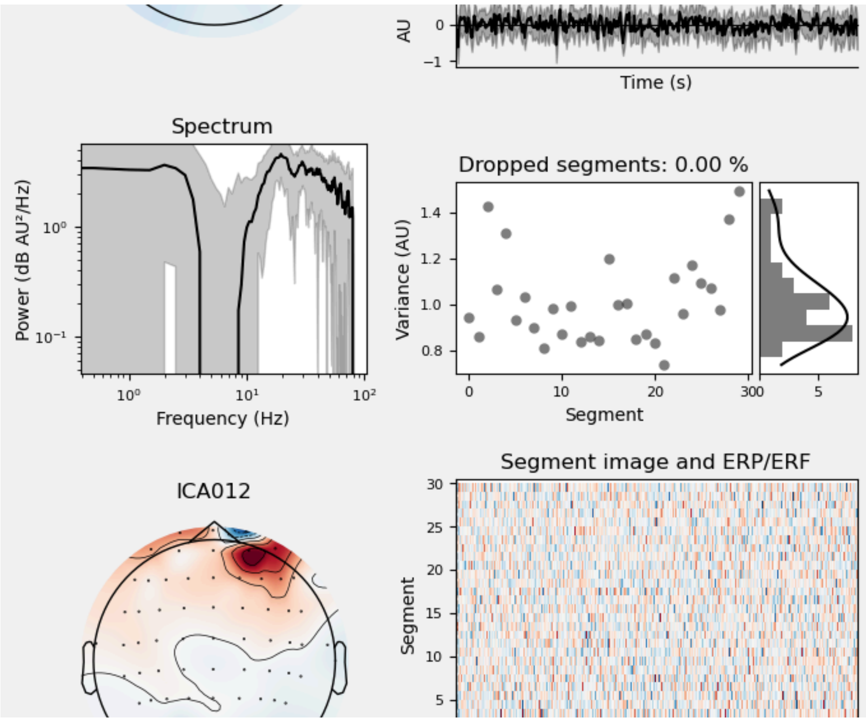





```
Manually found muscle artifact ICA components:     [6, 7, 8, 9, 10, 11, 12, 13, 14]
Automatically found muscle artifact ICA components: [9]
Downloading EEGBCI data
Downloading file 'S002/S002R01.edf' from 'https://physionet.org/files/eegmmidb/1.0.0/
Download complete in 03s (1.2 MB)
Extracting EDF parameters from C:\Users\ulewi\mne_data\MNE-eegbci-data\files\eegmmidb
EDF file detected
```

```
Setting channel info structure...
Creating raw.info structure...
Reading 0 ... 9759  =      0.000 ...    60.994 secs...
Filtering raw data in 1 contiguous segment
Setting up high-pass filter at 1 Hz

FIR filter parameters
---------------------
Designing a one-pass, zero-phase, non-causal highpass filter:
- Windowed time-domain design (firwin) method
- Hamming window with 0.0194 passband ripple and 53 dB stopband attenuation
- Lower passband edge: 1.00
- Lower transition bandwidth: 1.00 Hz (-6 dB cutoff frequency: 0.50 Hz)
- Filter length: 529 samples (3.306 s)

Fitting ICA to data using 64 channels (please be patient, this may take a while)
[Parallel(n_jobs=1)]: Done  17 tasks      | elapsed:    0.0s
Selecting by number: 15 components
Fitting ICA took 2.2s.
Creating RawArray with float64 data, n_channels=15, n_times=9760
    Range : 0 ... 9759 =      0.000 ...    60.994 secs
Ready.
Effective window size : 12.800 (s)
    Using multitaper spectrum estimation with 7 DPSS windows
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
Not setting metadata
30 matching events found
No baseline correction applied
0 projection items activated
```




AU
Time (s)
Spectrum
Power (dB AU²/Hz)
Frequency (Hz)
Dropped segments: 0.00 %
Variance (AU)
Segment
ICA012
Segment image and ERP/ERF
Segment