muse™ Developers
the brain sensing headband

Muse Direct | Available Data

Table of Contents

This is a list of all the data available from Muse Direct. For the data available from LibMuse, please see the API Reference for your platform.

1 EEG Data

Raw EEG

This is the raw EEG data for each channel on the headband as measured in microvolts. Filtering options, sampling rate, compression, and various other settings are configurable via presets.

OSC Path	/eeg
Units	uV
Datatype	floats
Resolution	Preset ID: 10, 12, 14 — Resolution: 10 bit Preset ID: 20, 21, 22 — Resolution: 12 bit Preset ID: AD, AE — Resolution: 16 bit
Range	0.0 - 1682.815 uV
Sampling rate	Preset ID: 10, 12, 14 — Sampling Rate (Hz): 220 Preset ID: 20, 21, 22 — Sampling Rate (Hz): 256 Preset ID: AD, AE — Sampling Rate (Hz): 500
Channel configuration	[TP9, AF7, AF8, TP10]

Resolution:

Preset ID	Resolution
10, 12, 14	10 bit
20, 21, 22	12 bit
AD, AE	16 bit

Sampling rate:

Preset ID	Sampling Rate (Hz)
10, 12, 14	220
20, 21, 22	256
AD, AE	500

Notch Filtered EEG

Notch filtered EEG is the raw EEG passed through a band stop filter to remove frequencies between 45 and 65 Hz inclusive. Notch Filtered EEG is not available for presets AB and AD.

OSC Path	/notch_filtered_eeg
Units	uV
Datatype	floats
Resolution	

Preset ID	Resolution

10, 12, 14	10 bit
20, 21, 22	12 bit

Range	0.0 - 1682.815 uV
Sampling rate	

Preset ID	Sampling Rate (Hz)
10, 12, 14	220
20, 21, 22	256

Channel configuration	[TP9, AF7, AF8, TP10]

EEG Quantization Level

When using a Muse 2014 headband with presets 10, 12, or 14, the EEG data is compressed. If there is too much variation in the signal, then the signal must be rounded off (estimated) when it is sent. To decrease the size of the data, the EEG value is divided by a number before it is sent. This is the number it is divided by.

Datatype	float
OSC path	/eeg/quantization
OSC data format	f
Range	1, 2, 4, 8, 16, 32, 64,128

2 Accelerometer Data

Raw Accelerometer Data

Accelerometer represent acceleration relative to gravity in the X, Y, Z directions, in that order. X, Y, Z are orientated on a right hand coordinate system with X pointing forward from the center of the head. These values are in G's where 1 G is the force of gravity, this is also known as "weight per unit mass" or "acceleration vector".
For an explanation of G-forces, see: http://en.wikipedia.org/wiki/G-force
Some relevant points:

- The g-force acting on a stationary object resting on the Earth's surface is 1g (upwards) and results from the resisting reaction of the Earth's surface bearing upwards equal to an acceleration of 1 g, and is equal and opposite to gravity. The number 1 is approximate, depending on location.
- The g-force acting on an object under acceleration can be much greater than 1g

For a visual representation of the axes, refer to the SDK API documentation

OSC Path	/acc
Units	g
Datatype	three floats

Resolution	<table><tr><th>Preset ID</th><th>Resolution</th></tr><tr><td>12, 14</td><td>10 bits</td></tr><tr><td>20, 21</td><td>16 bits</td></tr></table>
Range	-2 - 2g
Sampling rate	<table><tr><th>Preset ID</th><th>Sampling Rate (Hz)</th></tr><tr><td>12, 14, AB, AD</td><td>50</td></tr><tr><td>20, 21</td><td>52</td></tr></table>

3 Gyroscope Data

Raw Gyroscope Data

Gyroscope data is available for Muse 2016 headbands. Gyroscope data represents rotation in degrees per second about the X, Y and Z directions, in that order. X, Y, Z are orientated on a right hand coordinate system with X pointing forward from the center of the head.
For a visual representation of the axes, refer to the SDK API documentation

OSC Path	/gyro
Units	degrees per second
Datatype	three floats
Resolution	16 bits
Range	-245, 245 degrees per second
Sampling rate	52 Hz

4 Muse Elements Data

It is difficult to work with raw brain signals without a background in neuroscience or machine learning. Usually they are run through a series of computations to produce more useful features. The values given in this section are computed from the raw EEG values shown above. “**Muse Elements**” is our algorithm and signal processing pack for developers.

Raw FFTs for Each Channel

FFT stands for Fast Fourier Transform. This computes the power spectral density of each frequency on each channel. Basically, it shows which frequencies make up a signal, and “how much” of each frequency is present.

Each FFT contains 129 decimal values with a range of roughly -40.0 to 20.0. Each array represents

FFT coefficients (expressed as Power Spectral Density) for each channel, for a frequency range of 0-110 Hz (Muse 2014) or 0-128 Hz (Muse 2016) divided into 129 bins. We use a Hamming window of 1 second, then for the next FFT we slide the window 1/10th of a second over. This gives a 90% overlap from one window to the next. These values are used to compute the emitted algorithms.

Understanding Frequency Bins

The FFTs are calculated using a 256 sample window, which gives a transform that has 256 components and is symmetric (i.e. mirrored) around an additional component at 0Hz. In other words, you have 128 components, followed by one for 0Hz, and then the mirror image of the same components. This means you need only consider half of them (because the other half are the same, only reflected) plus the one for 0Hz at the centre, which gives you 129 in total.

To get the frequency resolution for the bins, you can divide the sampling rate by the FFT length, so in the case of Muse 2014: 220/256 ~ 0.86Hz/bin

So, the zeroth index of the FFT array represents 0Hz, the next index represents 0-0.86Hz, and so on up to 128*0.86 = 110Hz, which is the maximum frequency that our FFT with its 220Hz sampling rate can detect.

Absolute Band Powers

The absolute band power for a given frequency range (for instance, alpha, i.e. 7.5-13Hz) is the logarithm of the sum of the Power Spectral Density of the EEG data over that frequency range. They are provided for each of the four to six channels/electrode sites on Muse.
Since it is a logarithm, some of the values will be negative (i.e. when the absolute power is less than 1) They are given on a log scale, units are Bels.

OSC Paths	/elements/delta_absolute /elements/theta_absolute /elements/alpha_absolute /elements/beta_absolute /elements/gamma_absolute
Units	Bels (B)
Datatype	floats
Transmission frequency	10 Hz
OSC Data Format	Four channels (electrode sites) for each band power: ffff
Frequency Ranges*	(see table below)

Name	Frequency Range
delta_relative	1-4Hz
theta_relative	4-8Hz
alpha_relative	7.5-13Hz
beta_relative	13-30Hz

gamma_relative	30-44Hz

* The boundaries of the frequency ranges are inclusive of the end values. Where 2 ranges overlap, a frequency in the overlapping area counts in both ranges.

Relative Band Powers

The relative band powers are calculated by dividing the absolute linear-scale power in one band over the sum of the absolute linear-scale powers in all bands. The linear-scale band power can be calculated from the log-scale band power thusly: linear-scale band power = 10^ (log-scale band power).

Therefore, the relative band powers can be calculated as percentages of linear-scale band powers in each band. For example:

```
alpha_relative = (10^alpha_absolute / (10^alpha_absolute + 10^beta_absolute + 10^delta_absolute + 10^gamma_absolute + 10^theta_absolute))
```

The resulting value is between 0 and 1. However, the value will never be 0 or 1.
These values are emitted at 10Hz.

OSC Paths	/elements/delta_relative /elements/theta_relative /elements/alpha_relative /elements/beta_relative /elements/gamma_relative
Units	Bels (B)
Datatype	floats
Transmission frequency	10 Hz
OSC Data Format	Four channels (electrode sites) for each band power: ffff
Frequency Ranges*	

Name	Frequency Range
delta_relative	1-4Hz
theta_relative	4-8Hz
alpha_relative	7.5-13Hz
beta_relative	13-30Hz
gamma_relative	30-44Hz

* The boundaries of the frequency ranges are inclusive of the end values. Where 2 ranges overlap, a frequency in the overlapping area counts in both ranges.

Band Power Session Scores

The band session score is computed by comparing the current value of a band power to its history. This current value is mapped to a score between 0 and 1 using a linear function that returns 0 if the current value is equal to or below the 10th percentile of the distribution of band powers, and returns 1 if it's equal to or above the 90th percentile. Linear scoring between 0 and 1 is done for any value between these two percentiles.

Be advised that these scores are based on recent history and it will take a few seconds before having a stable distribution to score the power against. The estimated distribution is continuously updated as long as the headband is on the head. However, every time it's updated, the newest values are weighted to have more importance than the historical values. This means that eventually old values will not be present anymore in the estimated distribution. The half-life of the estimated distribution at any given point is around 10 s.

The score will start being calculated as soon as the headband has established a good connection with the skin. Whenever the headset loses connection with the head (as determined by the DRL/REF contact quality) the estimated distributions are reset. This means that when the headband is removed, the session data from any previous user will be cleared.

<table>
<tr><td>OSC Paths</td><td>/elements/delta_session_score
/elements/theta_session_score
/elements/alpha_session_score
/elements/beta_session_score
/elements/gamma_session_score</td></tr>
<tr><td>Units</td><td>Unitless</td></tr>
<tr><td>Datatype</td><td>floats</td></tr>
<tr><td>Transmission frequency</td><td>10 Hz</td></tr>
<tr><td>OSC Data Format</td><td>Four channels (electrode sites) for each band power: ffff</td></tr>
<tr><td>Frequency Ranges*</td><td><table>
<tr><td>Name</td><td>Frequency Range</td></tr>
<tr><td>Delta Session Score</td><td>1-4Hz</td></tr>
<tr><td>Theta Session Score</td><td>4-8Hz</td></tr>
<tr><td>Alpha Session Score</td><td>7.5-13Hz</td></tr>
<tr><td>Beta Session Score</td><td>13-30Hz</td></tr>
<tr><td>Gamma Session Score</td><td>30-44Hz</td></tr>
</table></td></tr>
</table>

* The boundaries of the frequency ranges are inclusive of the end values. Where 2 ranges overlap, a frequency in the overlapping area counts in both ranges.

5 Headband Status

These values can be used to determine if Muse is on the head properly and getting good contact. These values are emitted at 10Hz.

Headband On / Touching Forehead

A boolean value, 1 represents that Muse is on the head correctly.

OSC Path	/elements/touching_forehead
Datatype	int
Transmission frequency	10Hz

Headband Status Indicator / Horseshoe

Status indicator for each channel.

1 = good, 2 = mediocre, 4 = bad

OSC Path	/elements/horseshoe
Datatype	4 floats, 1 per channel
Transmission frequency	10Hz
Range	1 = Good 2 = Mediocre 4 = Bad

Real Time EEG Quality

Strict data quality indicator for each channel, 0= bad, 1 = good.

OSC Path	/elements/is_good
Datatype	4 ints, 1 per channel
Transmission frequency	10Hz
Range	0 = Bad 1 = Good

6 Artifacts

Blinks

A boolean value, 1 represents a blink was detected.

OSC Path	/elements/blink
Datatype	int
Transmission Frequency	10Hz
OSC Data Format	i

Jaw Clenches

A boolean value, 1 represents a jaw clench was detected.

OSC Path	/elements/jaw_clench
Datatype	int
Transmission Frequency	10Hz

7 Battery Data

OSC Path	/batt
Datatype	3 floats
Data format	[State of charge, Fuel gauge battery voltage, Temperature]
Units	State of Charge: %/100 - hundredths of percents Fuel Gauge Battery Voltage: mV Temperature: C
Range	State of Charge: 0 to 10000 Fuel Gauge Battery Voltage: 3000 to 4200 mV Temperature: -40 to +125C
Transmission frequency	0.1Hz

8 DRL/Ref Data

The Driven-Right-Leg (DRL) circuit has been used for about 50 years to reduce common-mode noise in biopotential amplifiers in applications that range from stationary equipment powered from the wall to battery-powered ambulatory monitors, and for systems that use gelled, dry, textile, and capacitive electrodes. The Driven Right Leg circuit is used to eliminate common-mode noise by actively cancelling it.

The reference signal is the one all other EEG values are derived from and is maintained around 1.65V. The DRL is driving the reference through the skin and adjusts the output based on noise fed back from the reference. If the headband is off the head the reference signal is not driven and the difference between the two values is significant, if on the head the difference is small.

OSC Path	/drlref
Datatype	2 floats
Data format	[DRL voltage, REF voltage]
Units	uV
Range	0 to 3300000
Sampling frequency	Same as EEG, depending on preset